Menlo Park Notebook #72 [N-80-03-31]

This notebook covers the period March-May 1880. Most of the entries are by Charles L. Clarke. Much of the book relates to the development of generators, including the jumbo dynamo. There are notes, calculations, and drawings of shafting and belting for dynamos; calorimeter tests of dynamos; and notes on jumbo dynamos for the Pearl Street central station, including a memorandum on questions to be asked of Charles T. Porter, whose steam engine was to be used for the jumbo. Also included are notes by Clarke on Henry Rowland's report on the electric light, draft letters by both Edison and Clarke in response to the American Machinist's article on Edison's dynamo, and a report by Clarke on Sidney H. Short's telephone. The label on the front cover is marked "Clarke." The book contains 280 numbered pages and has been used in both directions.

Filming order: pp. 1-201, 275-210 [in reverse page-number order], 272-280.

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$a + b = c$

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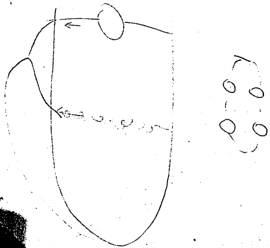

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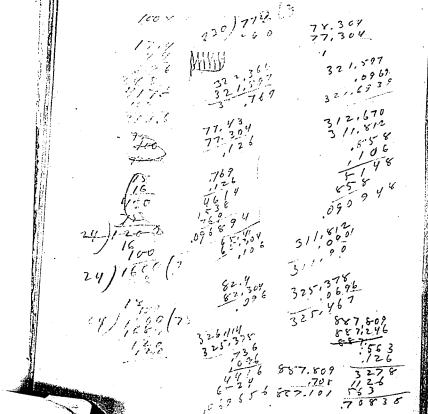

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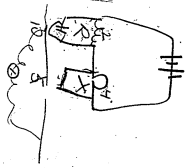

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Kings Treatise on the Science and Practice of the Manufacture and Distribution of Coal Gas, Edited by Thomas Newbigging. Vol. I

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	T.4781262		
221	0.1508792		
	0.1256553	1.4154	
	T.4788018		

222	0.1515843	1.4177	232	0.1584831	1.4404	242	0.1653334	1.4633	252	0.1720773	1.4862
	0.1263604			0.1332592			0.1460095			0.1468534	
	T.4795069			T.4864057			T.4932560			T.4999999	
223	0.1522883	1.4200	233	0.1591760	1.4427	243	0.1660155	1.4656	253	0.1727488	1.4885
	0.1270694			0.1339582			0.1407916			0.1475249	
	T.4802709			T.4870986			T.4939381			T.5006709	
224	0.1529607	1.4222	234	0.1598678	1.4450	244	0.1666965	1.4679	254	0.1734194	1.4908
	0.1277368			0.1346438			0.1414726			0.1481955	
	T.4808833			T.4877904			T.4946691			T.5013920	
225	0.1536625	1.4245	235	0.1605586	1.4473	245	0.1673764	1.4702	255	0.1740889	1.4931
	0.1284938			0.1353347			0.1422525			0.1488681	
	T.4815851			T.4884872			T.4952290			T.5020115	
226	0.1543631	1.4268	236	0.1612482	1.4496	246	0.1680553	1.4725	256	0.1747574	1.4954
	0.1291392			0.1360243			0.1428314			0.1495335	
	T.4822857			T.4891708			T.4959779			T.5026800	
227	0.1550626	1.4291	237	0.1619367	1.4519	247	0.1687331	1.4748	257	0.1754248	1.4977
	0.1298387			0.1367128			0.1435092			0.1502009	
	T.4829852			T.4898593			T.4966557			T.5033474	
228	0.1557307	1.4313	238	0.1625943	1.4541	248	0.1693805	1.4770	258	0.1760913	1.5000
	0.1305068			0.1374704			0.1442566			0.1508674	
	T.4836533			T.4905169			T.4973031			T.5040139	
229	0.1564280	1.4336	239	0.1632807	1.4564	249	0.1700563	1.4793	259	0.1767567	1.5023
	0.1311741			0.1380568			0.1449324			0.1515328	
	T.4843506			T.4912333			T.4979887			T.5046793	
230	0.1571242	1.4359	240	0.1639660	1.4587	250	0.1707310	1.4816	260	0.1774211	1.5046
	0.1319003			0.1387421			0.1455871			0.1521972	
	T.4850468			T.4919266			T.4986536			T.5053437	
231	0.1577891	1.4381	241	0.1646502	1.4610	251	0.1714046	1.4839	261	0.1780844	1.5069
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Rule

Multiply
Divide
Multiply

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George Carman

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$\bar{3}.3617278$	$\bar{3}.2304489$	$\bar{3}.1139434$
$\bar{4}.7759970$	$\bar{4}.6945181$	$\bar{4}.5280126$
$\bar{3}.4149733$	$\bar{3}.2787536$	$\bar{3}.1760913$
$\bar{4}.8280425$	$\bar{4}.6928228$	$\bar{4}.5801685$
$\bar{3}.4471580$	$\bar{3}.3424227$	$\bar{3}.2304489$
$\bar{4}.8612272$	$\bar{4}.7564919$	$\bar{4}.6945181$
$\bar{3}.4913617$	$\bar{3}.3802112$	$\bar{3}.2552725$
$\bar{4}.9054305$	$\bar{4}.7942804$	$\bar{4}.6683117$
$\bar{3}.5314789$	$\bar{3}.4149733$	$\bar{3}.3010300$
$\bar{4}.9455481$	$\bar{4}.8280425$	$\bar{4}.7780992$
$\bar{3}.5563025$	$\bar{3}.4471580$	$\bar{3}.3424227$
$\bar{4}.9703717$	$\bar{4}.8612272$	$\bar{4}.7564919$
$\bar{3}.5910646$	$\bar{3}.4771213$	$\bar{3}.3802112$
$\bar{3}.0051638$	$\bar{4}.8911905$	$\bar{4}.7942804$
$\bar{4}.3010300$	$\bar{3}.5051500$	$\bar{3}.4149733$
$\bar{5}.7780992$	$\bar{4}.9181192$	$\bar{4}.8280425$
$\bar{4}.6020600$	$\bar{4}.3010300$	$\bar{3}.4471580$
$\bar{4}.0161292$	$\bar{5}.7780992$	$\bar{4}.8612272$
$\bar{4}.7781513$	$\bar{4}.6020600$	$\bar{5}.3010300$
$\bar{4}.1922205$	$\bar{4}.0161292$	$\bar{5}.7780992$
$\bar{4}.9542425$	$\bar{4}.7781513$	$\bar{5}.4771213$
$\bar{4}.3683117$	$\bar{4}.1922205$	$\bar{4}.8511905$
$\bar{3}.$	$\bar{4}.8450980$	$\bar{5}.6989700$
$\bar{4}.4149692$	$\bar{4}.2591672$	$\bar{5}.1130392$

$\bar{9}.7781513$
$\bar{9}.1922205$

$\bar{9}.9030900$
$\bar{9}.3171592$

$\bar{9}.0000000$
$\bar{9}.4140692$

$\bar{9}.0413927$
$\bar{9}.4559619$

$\bar{9}.1139434$
$\bar{9}.5280126$

$\bar{9}.1760913$
$\bar{9}.5961605$

$\bar{9}.2041200$
$\bar{9}.6181892$

$\bar{9}.2304489$
$\bar{9}.6944181$

$\bar{9}.2787536$
$\bar{9}.6928228$

$\frac{\pi D^2}{4} = \pi r^2$

$\frac{D}{2} = r$

$\bar{9}.3222193$
$\bar{9}.7362885$

$\bar{9}.3617278$
$\bar{9}.7757970$

$\bar{9}.3802112$
$\bar{9}.7942804$

$\bar{9}.0000000$
$\bar{9}.4140692$

$\bar{9}.7781513$
$\bar{9}.1922205$

$\bar{9}.8450980$
$\bar{9}.2591672$

$\bar{9}.9542425$
$\bar{9}.3682117$

$\bar{9}.0414692$
$\bar{9}.4559619$

$\bar{9}.1139434$
$\bar{9}.5280126$

$\bar{9}.1461280$
$\bar{9}.5601972$

$\bar{9}.2041200$
$\bar{9}.6181892$

$\bar{9}.2304489$
$\bar{9}.6944181$

$\bar{9}.2787536$
$\bar{9}.6928228$

$\bar{9}.3222193$
$\bar{9}.7362885$

$\bar{9}.4772213$
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$\bar{9}.6020600$
$\bar{9}.0109292$

$\bar{9}.6985200$
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$\bar{9}.8450980$
$\bar{9}.2591672$

$\bar{9}.9030900$
$\bar{9}.3171592$

$\bar{9}.9542425$
$\bar{9}.3682117$

$\bar{9}.0000000$
$\bar{9}.4140692$

$\bar{9}.0791812$
$\bar{9}.4932504$

$\bar{9}.1139434$
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$\bar{9}.1461280$
$\bar{9}.5601972$

$\bar{9}.2041200$
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$\bar{9}.2304489$
$\bar{9}.6944181$

$\bar{9}.2515272$
$\bar{9}.6693417$

$\bar{9}.2787536$
$\bar{9}.6928228$

$\frac{\pi D^2}{4} = \pi r^2$

$\frac{D}{2} = r$

15705
7 8580
17708
15705
7 8 5

1.4142
2 8 2 8
1 4 1 4 2
1 4 1 4 2
1 4 2 3

3.1423
3.1423
1 2 5 6 9
1 2 5 6 9
1 2 5 6 9

113.14159
7 8 5 4

.441
.441
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2 7 6
1 4 4
.2 7 2 3 2 1
.7 8 5 4

8 5 0 0 8 9
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1 7 0 2 1 6 8
1 4 5 7 6 4 2
.7 6 5 9 1 3 9 3 6

144) 5 5 5 , (3,8 5 4 2
4 3 2
1 2 3 0
1 1 5 2
7 8 0
7 2 0
6 0 0
5 7 6
2 4 0

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10020   4.000000000          T.3280610
        0.66403050           T.2231519 1672
        2.00000000
        2.66403050
        D.46131-

10040   4.00173371
        0.66403050
        2.00056665
        2.66459736           T.32979472
        D.46227              T.22448562 1678

10080   4.00346053
        0.66403050
        2.00173027
        2.67376077           T.33152154
        D.46318              T.2286/244 1685

10120   4.00518051
        0.66403050
        2.00259026
        2.66662076           T.33324152
        D.46411              T.22633242 1692

10160   4.00689371
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        2.00344486
        2.67047736           T.33495472
        D.46503              T.22804562 1698

10200   4.00860017
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        2.00430009
        2.66833059           T.33666118
        D.46594              T.23175208 1705

10240   4.01029996
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        2.00514998
        2.67314048           T.33836096
        D.46685              T.23345186 1712

10280   4.01199311
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        2.00599656
        2.67002704           T.34005412
        D.46776              T.23514502 1719
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        2.00767988
        2.67171038           T.34342076
        D.46958              T.23851 16 1732

10400   4.01703334
        0.66403050
        2.00851667
        2.67255717           T.34509434
        D.47049              T.24018528 1739

10440   4.01870050
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        2.00935025
        2.67338075           T.34676150
        D.47139              T.24185240 1745

10480   4.02036128
        0.66403050
        2.01018064
        2.67421114           T.34842228
        D.47218              T.24351318 1752

10520   4.02201574
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        2.67503637           T.35007674
        D.47309              T.24516764 1759

10560   4.02366392
        0.66403050
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        D.47409              T.24681582
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Sq. root 2 = 1.4142, log = 0.1505708

2.66490305
2.5713 5197 3.326
2.4.18 5 8 5 5 7 5 .266
2.4.9 6 3 9 0 0 0 5 .237
2.3.7 4 5 3 5 9 5 .266
2.2.7 7 3 5 3 7 .189

2.66489736
2.5.4 9 3 8 4 5 6 2 .327
2.4.2 6 3 5 3 6 9 3 .267
2.3.1 8 5 6 7 3 6 .237
2.3.1 5 0 0 6 4 .207
2.2.7 5 7 7 9 2 .189

2.66576077
2.5.5 5 2 4 9 9 2 3 .328
2.4.2 7 1 8 7 7 7 .267
2.3.6 7 7 2 7 7 .237
2.3.1 6 2 1 9 5 7 .207
2.2.7 2 2 5 3 3 7 .189

2.66662076
2.5.6 1 0 0 8 8 6 2 .328
2.4.2 5 8 9 7 7 .267
2.3.6 1 5 5 5 6 .237
2.2.1 7 5 9 9 5 .207
2.2.7 7 1 5 3 6 .189

2.66747736
2.5.7 1 6 8 6 6 5 4 7 .328
2.4.2 5 6 7 2 5 3 4 .267
2.3.6 1 4 4 5 3 4 .237
2.3.1 7 5 7 1 4 .207
2.2.7 8 3 9 9 6 .189

2.66833059
2.5.8 7 8 1 9 7 9 .328
2.4.2 9 7 5 7 7 9 .267
2.3.6 1 5 3 0 0 5 .237
2.3.2 5 3 3 3 9 .207
2.2.7 9 2 5 3 7 .189

2.669 18048
2.5.9 1 6 6 8 1 4 2 .328
2.4.3 6 6 0 7 9 4 .267
2.3.6 1 5 5 6 9 5 .237
2.3.2 6 0 1 3 5 .207
2.2.8 0 7 0 3 8 .189

2.67002706
2.5.9 5 1 6 2 6 3 .327
2.4.3 9 4 0 6 .267
2.3.6 4 5 3 5 .237
2.3.2 0 5 3 5 6 .207
2.2.8 0 9 9 3 6 .189

2.67085035
2.5.9 0 3 5 8 3 5 .327
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2.2.8 1 7 9 2 9 .189

2.67170385
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2.3.7 0 6 5 3 .237
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2.2.8 2 2 3 3 .189

2.67255470
2.5.9 2 3 0 3 6 3 .327
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2.3.7 0 7 5 .237
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2.67333501
2.5.9 2 8 6 8 9 5 .327
2.4.3 9 6 0 7 5 .267
2.3.7 0 9 5 .237
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2.2.8 2 9 3 .189

2.67342118
2.5.9 2 3 7 0 0 3 .327
2.4.3 9 3 6 3 8 .267
2.3.7 0 9 .237
2.3.2 3 9 7 .207
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2.67503537
2.5.9 2 4 5 2 7 5 7 .327
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2.3.2 3 7 3 2 6 .207
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2.0.3 5 3 7 5 9 .109
2.0.1 3 5 1 9 0 .135

2.66489736
2.2.1 3 3 5 6 .163
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2.0.9 3 5 7 .109
2.0.6 1 0 9 .135

2.66747736
2.2.1 7 1 8 .113
2.1.6 7 5 3 .139
2.1.3 2 7 .109
2.0.9 4 1 .135
2.0.6 5 .109
2.0.3 9 .135

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2.1.6 8 4 .109
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2.0.9 7 .109
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2.0.2 .135

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2.2.1 8 1 .109
2.1.6 9 .135
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2.0.9 8 .135
2.0.6 7 .109
2.0.4 .135
2.0.2 .109

2.67002706
2.2.1 8 4 .135
2.1.7 0 .109
2.1.3 5 .135
2.0.9 9 .109
2.0.6 8 .135
2.0.4 .109
2.0.2 .135

2.67085035
2.2.1 9 .109
2.1.7 1 .135
2.1.3 6 .109
2.0.9 9 .135
2.0.6 9 .109
2.0.4 .135
2.0.2 .109

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2.1.7 2 .109
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2.0.2 .109

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2.0.4 .109
2.0.2 .135

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2.0.2 .135

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2.2210 0637 166
2.1725 8807 142
2.1329 5677 126
2.0994 2617 120
2.0704 8717 115
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2.1337 9035 [illegible]
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2.1027 7346 127
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2.0485 8346 112
2.0253 5086 106

Weight-page 70

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8.000000
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4.000000
7.500000

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0843	3248	3273,25
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0849	3273	3325,91
0853	3286	3351,65
0856	3299	3377,99
0860	3312	3404,43
0863	3325	3430,98
0866	3338	3457,63
0870	3351	3484,38
0873	3364	3511,23
0876	3376	3538,19
0880	3389	3565,25
0883	3402	3592,41

Page 84

9400	3,97312779 1,98656640 T.65059491 T.30118902 T.19622246	7,94625558 3,74503439 3,97312779 7,78221660 ~~7,85[illegible]~~
9440	3,97497220 1,98749860 T.65151651 T.30303300 T.~~19596886~~	7,99999440 3,75590321 3,97497220 7,78906601
9480	3,97685083 1,98840042 T.65243491 T.30486994 T.~~19990050~~	7,95361166 3,76227847 3,97685083 7,78549649
9520	3,97863685 1,98931850 T.65333491 T.30669980 T.20173336	7,95727738 3,76631219 3,97863685 7,78772250
9560	3,98049579 1,99022290 T.65425895 T.30857190 T.20355946	7,96081158 3,77066039 3,98049579 7,78955960
9600	3,98227212 1,99111356 T.65516611 T.31033322 T.20537678	7,96495424 3,77736305 3,98227212 7,77733593

		Total Weights
9640	3,9840770	7,9685190
	1,9920385	3,7777242, Mag.
	F,6560690	3,9840770 84
	T,3172380	T,7931651
	T,2071736	

9680	3,9858754	7,9717508
	1,9929377	3,7808589
	F,5696982	3,9858754
	T,3139364	T,7949635
	T,2089720	

9720	3,9876663	7,9753326
	1,9938332	3,7849207
	F,6578639	3,9876663
	T,3157279	T,7967554
	T,2107630	

9760	3,9894498	7,9788996
	1,9947249	3,7877877
	F,6587556	3,9894498
	T,3175108	T,7985379
	T,2125464	

9800	3,9912261	7,9824522
	1,9956131	3,7914403
	F,6596436	3,9912261
	T,3192872	T,8003742
	T,2143228	

9840	3,9929951	7,9859902
	1,9964976	3,7950783
	F,6605281	3,9929951
	T,3210562	T,8020832
	T,2160941	

		Total Weights
9880	3,9947569	7,9895138
	1,9973785	3,7986019
	F,6614090	3,9947569
	T,3228180	T,8033450
	T,2177536	

9920	3,9965117	7,9930234
	1,9982559	3,8021115
	F,6622864	3,9965117
	T,3245728	T,8053998
	T,2196084	

9960	3,9982593	7,9965186
	1,9991297	3,8056067
	F,6631602	3,9982593
	T,3263209	T,8073474
	T,2214560	

.40 × x = 1

x = 1/.40 = 40)1.00(1.25
80
200
200

.60 × x = 1

x = 1/.60 = 60)1.00(1.66
60
400
360
40

1 ⅔ ×

2π = 41 2r = R

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T, 0.0.0.0.4.3.0

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T, 0.2.3.4.9.4.4.4
T, 0.0.1.0.4.0.0

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T, 0.0.0.1.5.5

T, 6614090
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T, 0.2.3.3.2.1.8
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T, 6621.5.5.7
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T, 6631602
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T, 1.0.1.3.5.9.2.6.1
T, 0.0.2.6.9.8.7

13.2.5
.5
6625
3.5
185

Small pulley	25 lb.	2 bearings 3 inches Main shaft
Large "	70 lb.	
Driving "	280 lb.	
2 Idler "	120 lb. together	
Coupling	150 lb.	

Main shaft 23.56 lb per ft. 9 ft. long.

10" Rear pulley 135 lb. 1" diam. shaft.

10" Dynamo armature pulley 1" diam shaft

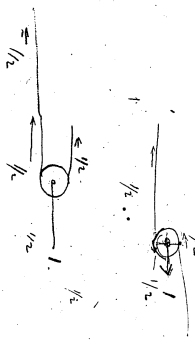
Belt & drive counter shaft - 30 lb.

Bearings 2 1/4".

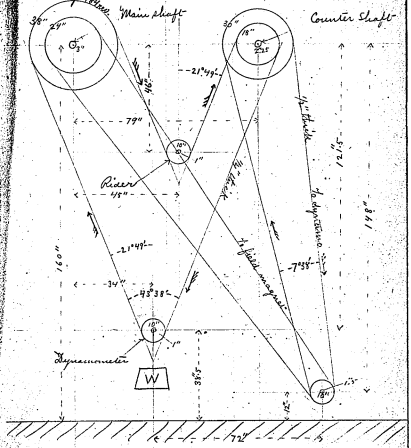
Counter shaft, 4 bearings.

18" pulley	60 lb.
2, 24" "	150 lb. together
30" "	90 lb.
" " "	90 lb.
2, 24" "	150 lb. together

Counter. 13 1/4 lb. per foot, 15 ft. long.



Sketch of shafting and belts from main shaft through dynamometer (Edisons) to dynamo machine. Scale 30 inches to 1 inch.



All dimensions are marked in inches

Fig. 1. April 16th 1880

R. Estimated by Mr. Kruse.

Weight on Main Shaft from dead load. Two bearings 3 inches diam.	Pulley	25 lbs.
	"	70 lbs.
	Main "	200 lbs.
	"	60 lbs.
	"	60 lbs.
	Coupling	150 lbs.
	Shafting 9' long, 23.58 lbs per ft.	212 lbs
Total weight		777 lbs.

This weight is assumed as equally divided between the two bearings

∴ Dead weight on each bearing 389 lbs.

Weight of rider about 135 lbs.

Weight on Counter Shaft from dead load, Four bearings 2½ inches diam.	Pulley	60 lbs.
	"	75 lbs.
	"	75 lbs.
	"	90 lbs.
	"	90 lbs.
	"	75 lbs.
	"	75 lbs.
	Shafting 15 ft. long 13.25 lbs per ft.	199 lbs
Total weight		739 lbs.

This weight is assumed as equally divided between the four bearings

∴ Dead weight on each bearing 185 lbs.

The total weight of belting running from main shaft through dynamometer to counter shaft, and from counter shaft to dynamo is about 50 lbs. The weight on counter shaft due to belting will be weight of belt from counter shaft to dynamo 20 lbs. plus

half the weight of belt from main to counter shaft, a total of 35 lbs. The weight on main shaft due to belting will therefore be 15 lbs. Hence

Total dead weight of main shaft
792 lbs.
" " " on each bearing
396 lbs.

Total dead weight of counter shaft
774 lbs.
" " " on each bearing
193.5 lbs.

Weight of armature of dynamo complete with pulley 170 lbs.

135) 54.5 (.40037 Nat. tan. of angle
540
000
950
925
25
21° 49'

150) 10.00 (.066666
900
1000 Nat. sin. of angle
900
100
3° 49'

Thus the angle of the belt over rider and dynamometer pulley is 43°38' and over dynamo pulley is 7°38'. The other parts are parallel.

76 The speed of pulleys and of power transmission by belts must be made upon the assumption that the diameter of pulleys are increased by the thickness of belt.

Diam. (with belt) of main pulley 38".25

Circumference 120".166

Speed of belting 22110".58

or 1842.55 ft.

This is for main shaft.

The dynamometer and under pulleys have, Diam. 10".25

Circumference 32".2

Rev. per m. 686.6

3.1416
10.25
15.7080
6283.2
3.1416
32.2011600

32.2/22110.58/686.6
193 2 X 11
2770
2576
1745
1932
2138

The diam. of the bearings is 1".77

and Circumference 3".1416

3.1416
686.6
15.7080
188496
25132.8
188496
2157.02256

Surface speed of bearing per m. 2157".

or 179.8 ft.

The main pulley on counter shaft has diameter (with belt) 18".25

Circumference 57".334

3.1416
18.4
25132.8
31416
7854
573332

and, since belt speed is 22110.58 the

No revolutions per m. 385.6

57.334/22110.58/385.6
172002 7
491038
459672
323660
286670
369900

The diam. of bearings is 2".25

Circumference 7".0686

3.1416
2.25
15 7080
6 2832
6 2832
7.0686000

and, since the no rev. per m. is 385.6 the surface speed of bearings will be 273"

7.0686
385.6
42 4116
35 3430
56 5488
21 2058
2731.6521.6

or 227.7 ft.

The dynamo pulley on counter shaft has diam. (with belt) 30".5

3.1416
30.5

Circumference, 95".8888

and, since no. of rev. per m. is 385.6 the surface speed and speed of belt to dynamo will be 36948"

95.8888
385.6
5749.1328
4790.9440
7665.8304
2874.5664
36947.2928

or 3079 ft.

The pulley on armature has diam. (with belt) 10".5

3.1416
10.5
15 7080
31 4160
32.9868 0

Circumference 32".99

Therefore the no. of revolutions per minute is 1120.

32.99/36945.00/1120
32.99 x 1
39 58
32 99
65 90
65 90

The diam. of bearing is 1".5

Circumference 4".7124

3.1416
1.5
15 7080
31 4160
4.7124
1120
94 2480
47 1240
47 1240
5277.8880

Therefore surface speed of bearing is 5277.9"

or 439.8 ft.

1st case.

Assume that we start from the dynamo pulley with 10 H.P. or 330000 ft-lbs. per minute.

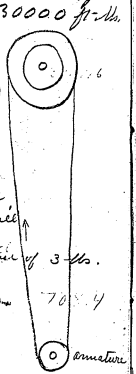
Coefficient of friction is taken as .05 (See page 83)

The weight of armature and pulley complete is 170 lbs. Since belt speed is 3079 ft. the strain will be about 108 lbs. which will leave 62 lbs pressure on armature or friction resistance of 3 lbs. at 439.8 ft. per m.

The power consumed is therefore 1317.4 ft. lbs.

439.8
3
1317.4

which added to the 10 H.P. consumed in induction &c gives 33131.7 ft. lbs.



This weight of 108 lbs. may be considered as increased on dynamometer belt in ratio of 305 to 18 or 180 and adding 3 lbs. for extra to transfer friction power to counter shaft we have 108 + 186 = 294 lbs the pressure due to strain on belts

The weight of counter shaft with pulleys &c is 774 lbs. (See page 74) and the resistance due to friction (774+294)0.05 = 53.25 lbs. which resistance is overcome at the speed of 227.7 ft. per minute.

The power consumed is therefore 12125 ft. lbs.

227.7
38.7
7593.99
18216
6831
8811.99

making total power consumed to this point 343442 ft. lbs.

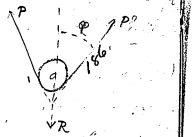
Transferring this to the dynamometer belt which has a speed of 1843 ft. per min. the strain upon the power side

of that belt will be 186 lbs.

We will assume in obtaining the weight lifted at the dynamometer pulley that no power is consumed in friction then

$R = 2P\cos.\varphi$.

$R = 2P\cos.21°49'$.



$R = 345$ lbs. which will be the weight lifted when 342550 ft. lbs. per m. pass the dynamometer.

The resistance due to friction will be 17.25, which resistance is overcome at the speed of

179.8 ft. per minute, consuming 3102 ft. lbs. a total of 346544 ft. lbs. or 16544 ft. lbs. due to friction, or $\frac{1}{2}$ H.P.

When the arm of the rudder is properly balanced the small amount of friction due to it may be neglected as practically there is no pressure on the bearings. The weight on dynamometer 345 lbs. equally divided between main and counter shafts will increase friction to

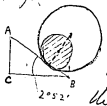
$3515 + 16544 =$

20059 ft. lbs.

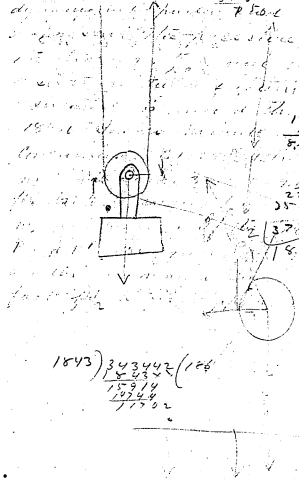
No allowance is made for stiffness of belts as they have been used some time and are pliable.

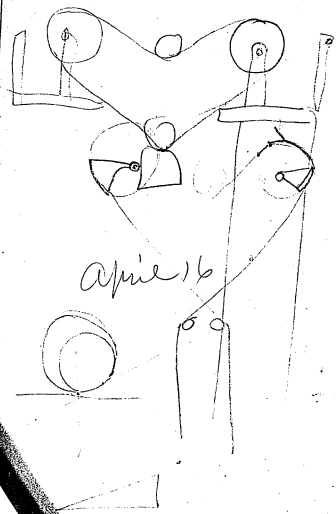
Assume the coefficient of friction to be according to good authorities, for bearings well lubricated, to be .05, the angle of friction is 2°52'.

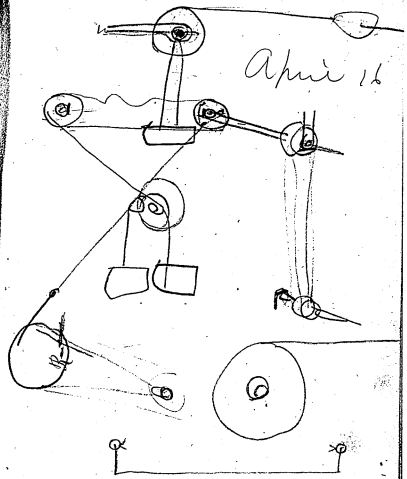
Fig. 3

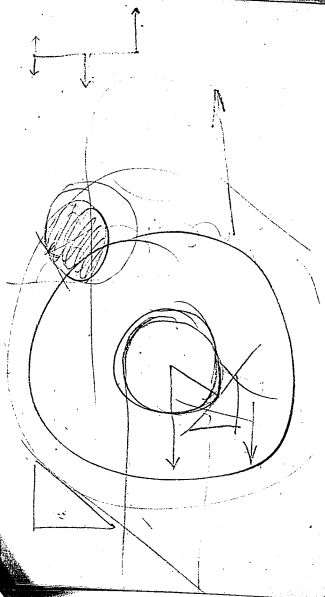


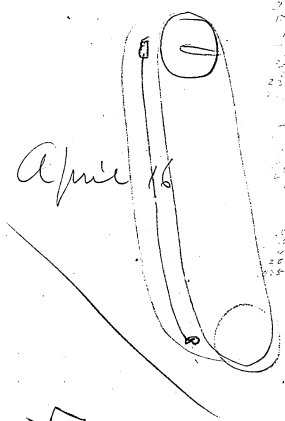
The pressure on the bearing surface due to the shaft running up the side of the loose bearing will be in the ratio to the downward pressure of BC to AB or 1 to 1.001 and can be neglected without appreciable error, being less than ½% in calculation of friction. The loss will be about balanced by the gain in neglecting stiffness of belts.




April 16


April 16



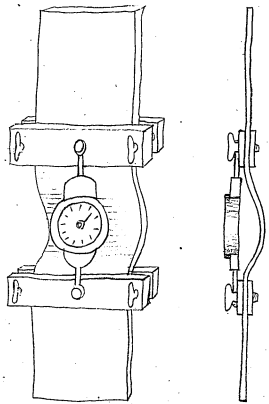


April 16

173
10.7
1.0.3
.094
10.3
.0484

April 17, 1880

Clark



American Machinist
Report on efficiency of
Edison dynamo.

It is stated that the first experiment is "to show the power consumed by the generator, the armature being 9 1/4 inches diameter and 9 inches face

1092 − .7(t − .32)

t − 32° = t − 212° + 180°

1092
260
766

299.113

331.113
32
299.113
305
1495515
899339
94229465

606.5
9
5)5455
1091.7

2.5
1.224
207.884

1091.7
32
299.113
305
1495515
899339
94229465
1091.7
32
1214.929465

75
32
43
305
215
129
13115

1091.7
1104.815
32
7136.815

1214.929465
207.884
1007.045
32
975.2045

1091.7
207.884
883.816

11).300(.027
22
80
77
.04) 0

15.60
14.01
1.59

15.6)1.590(1
1560(

5 .3

15.68)14.010(.95
~~940~~
1404
700

19.9).1.350(.068
1194
1260

)7.58)6.64(8
604
680

41.39).3100(7
5573

5.58)4.08(.730
4068
640

15.68).3.30(.9
1.5

10

5.58)4.08(7
4.06

7.58) 6.64(8
600
680

1151)2600(2.3
2302
3980

1210.823
1210.576
.247
.326
1482
494
741
.080522

1151)17411)1225
1137
2600
2300
2880
2303
1576

63
304
.326

111.113
110.110
1.003
59
9027
5055
.591177

1210.576
.081
1210.657
110.7
1089.957 units

110.11
110.7

per lb. of water at 71.63 pressure from temp. 110.590

161573.28
1089.96
96943968
14541595 2
14541595 2
161573 28
177665 97.86 88 units the total consumed.

70.
69.324
.676

1210.326
1210.074
.252
.696
1512
2268
1512
.175392

1210.074
.175
1210.249
150.542
1029.707 no. units per lb. of water from 180° to 70 lb. pressure.

1029.707)177665 97.86 88(172540
1029707 XXXX
7469527
7207949
2615788
2059414
5563746
5148535
4152118

1615 73
1100
1615 7300
5157 3
1029.7) 1777 3029 6.0 (1726 03
1029 7 7 7 7
74 760
72079
2681 3
2 6 5 9 4
6 2 1 9 0
6 1 7 5 2
4 0 5 0 0
3 8 5 9 7
7 7 0 3 0

.1305
1100
14300
5 5 7 9 00
1 0 9 1 7
32.
1178.6

$\log (v^{r-1})^{r-1}$

$\frac{dv^{r-1}}{v^{r-1}}$

$r-1 \log \frac{1}{v}$

$r-1 \cdot \frac{dv^{-1}}{v^{-1}}$

~~dv~~

$r-1 \log v^{-1}$

$r-1 \frac{dv^{-1}}{v^{-1}}$

$-v^{-1} dv$

$\log v^{-(r-1)}$

$\log v$

v^{r}

$v^{r} dv$

331.113
32.
299.113
.695
1 4 9 5 5 6 5
2 6 9 2 0 1 7
1 7 8 4 6 7 8
2 0 7.8 8 3 5 3 5

.695
180
5 5 6 0 0
6 9 5
1 2 5 1 0 0

1 0 9 1.7
1 2 5 1.1
9 6 6.6

$\log \left(\frac{1}{v}\right)^{r-1} - \log \left(\frac{1}{v_0}\right)^{r-1} = \log r - \log r^0$

$\log \frac{\left(\frac{1}{v}\right)^{r-1}}{\left(\frac{1}{v_0}\right)^{r-1}} = \log \left(\frac{r}{r^0}\right)$

$\log \left(\frac{\frac{1}{v}}{\frac{1}{v_0}}\right)^{r-1} = \log \left(\frac{r}{r_0}\right)$

$\frac{r}{r_0} \left(\frac{v}{v_0}\right) = \frac{p}{p_0} \left(\frac{v_0}{v}\right)^{r}$

$\frac{p_0 v_0}{r-1} - \frac{p_0 v_0^{r}}{v^{r-1} v}$

~~$p_0 v_0 v^{r-1} - p_0 v_0^{r} v$~~

$\frac{1}{r-1} \left(p_0 v_0 - \frac{p_0 v_0^{r}}{v}\right)$

$\frac{p_0 v_0 \left(\frac{v_0}{v}\right)^{r-1} v^{1-r}}{1-r}$

$2 \times dx$

$2 x^{2-1}$

$\frac{v^{1-r} dv}{1-r}$

$$\cancel{+\frac{p_0 v_0}{\gamma-1}\left(1-\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right)}$$

$$\cancel{-\frac{p_0 v_0}{\gamma-1}\left(1-\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}\right)}$$

$$\cancel{-\frac{p_0 v_0}{\gamma-1}}$$

$$v = \left(\frac{c}{p}\right)^{\frac{1}{\gamma}}$$

$$v = \frac{c}{p}$$

$$\left(\frac{c}{p}\right)^{\frac{1}{\gamma}} = \frac{c}{p}$$

$$\frac{p_0 v_0}{\gamma-1}\left\{1-\frac{v_0^{\gamma-1}}{v^{\gamma-1}}\right\}$$

$$\frac{p_0 v_0}{\gamma-1} - \frac{p_0 v_0^{\gamma}}{v^{\gamma}(\gamma-1)}$$

$$\frac{p_0 v_0 v - p_0 v_0^{\gamma}}{v^{\gamma}(\gamma-1)}$$

$$p_0 v_0\left(\frac{v - v_0^{\gamma-1}}{v^{\gamma}(\gamma-1)}\right)$$

between limits v_0 and v

$$p_0 (v_0)^{\gamma}\left[\frac{v^{1-\gamma}}{1-\gamma} - \frac{v_0^{1-\gamma}}{1-\gamma}\right]$$

$$p_0 (v_0)^{\gamma}\left[\frac{v^{1-\gamma} - v_0^{1-\gamma}}{1-\gamma}\right]$$

$$p_0 v_0^{\gamma}\left[\frac{v_0^{1-\gamma} - v^{1-\gamma}}{\gamma-1}\right]$$

$$\frac{p_0 v_0}{\gamma-1}\left[v_0^{0} - v^{1-\gamma} v_0^{\gamma-1}\right]$$

$$\frac{p_0 v_0}{\gamma-1}\left[1 - \frac{v_0^{\gamma-1}}{v^{\gamma-1}}\right]$$

$$\frac{p_0 v_0}{\cancel{\gamma-1}} \times \frac{\cancel{\gamma-1}}{p v}\left(\frac{1-\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}}{1-\left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}}\right)$$

$$\frac{p_0 v_0}{p v}\left(\frac{(p_0)^{\frac{\gamma-1}{\gamma}} - (p)^{\frac{\gamma-1}{\gamma}}}{(p_0)^{\frac{\gamma-1}{\gamma}}}\right)\left(\frac{(p)^{\frac{\gamma-1}{\gamma}}}{(p)^{\frac{\gamma-1}{\gamma}} - (p_0)^{\frac{\gamma-1}{\gamma}}}\right)$$

$$\frac{(p)^{\frac{\gamma-1}{\gamma}} p_0 v_0}{(p_0)^{\frac{\gamma-1}{\gamma}} p v}\left(\frac{(p_0)^{\frac{\gamma-1}{\gamma}} - (p)^{\frac{\gamma-1}{\gamma}}}{(p)^{\frac{\gamma-1}{\gamma}} - (p_0)^{\frac{\gamma-1}{\gamma}}}\right)$$

Now $\frac{p_0 v_0}{p v} = \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}$

$$\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}} \times \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{p_0 v_0}{\gamma-1} \times \frac{\gamma-1}{p v}\left(\frac{(p_0)^{\frac{\gamma-1}{\gamma}} - (p)^{\frac{\gamma-1}{\gamma}}}{(p_0)^{\frac{\gamma-1}{\gamma}}}\right)\left(\frac{(p)^{\frac{\gamma-1}{\gamma}}}{(p)^{\frac{\gamma-1}{\gamma}} - (p_0)^{\frac{\gamma-1}{\gamma}}}\right)$$

$\frac{1}{\gamma-1}(p_0 v_0 - p v)$ expended

$$\cancel{\frac{1}{\gamma-1}}$$

$$\begin{array}{r} 169 \\ 238 \\ \hline 407 \end{array} \qquad 407) \overline{32000}(\ldots$$

$$\begin{array}{r} 32000 \\ 32000 \\ \hline 3120 \end{array}$$

$$\frac{\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}} - 1}{1 - \left(\frac{p_0}{p}\right)^{\frac{\gamma-1}{\gamma}}}$$

$$\frac{(p)^{\frac{\gamma-1}{\gamma}} - (p_0)^{\frac{\gamma-1}{\gamma}}}{(p_0)^{\frac{\gamma-1}{\gamma}}} \times \frac{(p)^{\frac{\gamma-1}{\gamma}}}{(p)^{\frac{\gamma-1}{\gamma}} - (p_0)^{\frac{\gamma-1}{\gamma}}}$$

$\left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}$ 1000000)10.64 000 000 (0001064

10 000 000
6 400 000
6 000 000
4 000 000 00
4 000 000 00

4/2.1416
.7854

.7854).00001064000(135
.7854
2 7860
2 3562
4 2980
3 80

.00001064
.7854
4 2560
5 320
8 512
7448
.0000835664
.0000 1783 280

.000042

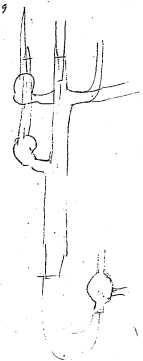
.000042) 396 000 (9412
378 ×
18 0
16 8
1 200

$p = Ar$ $A = \frac{p}{r}$
$dp = A\,dr$
$dy = p\frac{dr}{r}$

$r^{-1}dr = v^{-1}dv$
$\frac{dr}{r} = \frac{dv}{v}$
$\log r = \log v$
$r = v$

33000
420
660000
330000
44.3) 3 960 000 (8939
3 54 4 ×
4 160
3 987
1 730
1 329
4 010
9443 000 000
0009

772) 396 0000 (1129
3 560 ×
1 000
7 920
2 880
7 560
3 60



3.46
55
2076
2076
228.36

14.26
46.1
85 56
85 56
941.16
941.16
5646.96
941.16
941.16
37646.4
897044
85 5782.1 / 4 5-6 / 941.2
81
184 / 757
736
1841 / 2582
1841 / 2581
1842 / 301 14
85 5782.2896
5-2148.2896
8336 33.710 / 913.3
37
228.36
228.36
137016
68508
182688
45572
52148.2896

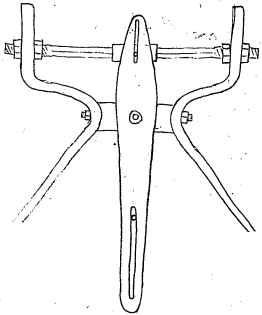
181 / 236
181
1823 / 5533
5-5
1824 / 5577
1824
194.18
913.3.
3425 4
3425 4
1918
10276 2
435-60. / 1042 80.5994 / 2.39
871 20 / 18
1716 05
1306 80
409 259
392 040
27 33
20 39
1.34

This said to have 2 Daniells cells connected to the magnet acting.

Correction = so that there was an Electromotive force of two Daniell Cells on the field magnet, which consumed about 250 feet lbs; this was nothing but a preliminary test and you were requested to throw this out, which was accomplished.

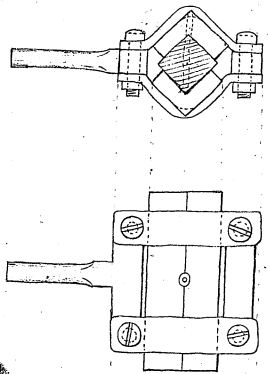
You say that with machine on a ~~[illegible]~~ fast and with chop shaft + Commutator

Indicator motion. May 31, 1880



Running that the Card A gave 9.59 h.p. when the Belt was thrown off of the Dynamo machine the Indicator Card B gave 4.15 horse power showing that the friction of the various trains & machinery consumed was 5.42 h.p. Now as over a dozen of my young men at the Laboratory have turned the dynamo by a hand

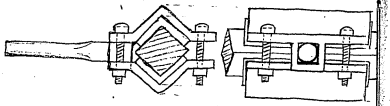
May 31, 1880.



power machine through an intermediate belt at the rate of 1000, per minute, it is apparent that there is an enormous discrepancy between ~~[illegible]~~ your 5.42 hp and the power of one man =

after field was taken off the difference by your indicator and between the machine running free & when the ~~work~~ field was on was 1.51. hp

(which is stated as E.M.F. Force equal to 2 Daniell's cells)



Either use the arm, page 100, or a bar as shown below, the guide pins a, b, c, d, being on a spindle e which is free to turn.

as a man can turn on the hand power nearly the same speed with the field off as on the 1.51 h.p. shows an enormous discrepency. In your article you say "difference between the machine running free & connected", you do not say "how connected", whether the field magnet, or the induction bobbin; Even to an expert this without any explanation was

be totally blind -

You say a coil of wire
said to be 174 Ohms.
The resistance of the
coil was one ~~[illegible]~~
four hundredth of
an ohm,

You say that the tank
should be of wood
to prevent conduction
of heat through the
sides ~~of the tank~~
The very essence of all

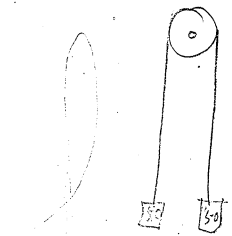
Calorimeter is that the
tank should be of metal
preferably a metal which
conducts heat the best.
& Copper is always
Employed, to the end that
the temperature of the
tank should be the
same as the water
otherwise no calculations
of the heat of the tank
can be obtained,
the radiation of the

low temperature is an
Extremely small fraction
of the total heat. it is
so small that in nearly
all Experiments it is
neglected. ~~at high~~
~~temp~~ & it may be
Entirely neglected
if the temperature of the
water is started as
much below the
atmosphere as it is
brought above it by
the storage of Energy
in the coals

You say, in first calorimeter test,
173 lbs of water.
·23 iron
·65 of wood,
·05 - Copper
whereas as the wood was
·65. you have multiplied
it not correctly =

---

1. You assumed that the
pressure ~~on~~ at the Cylinder
was the same as the boiler,
neither did you take
into consideration or correct
the pressure gauges, sometimes
there are 13 lbs diff between
the two gauges, &



You have in first experiment the specific heat of copper as .049 whereas it should be .094 (a typo. error as the result in Units of Heat column is correct).

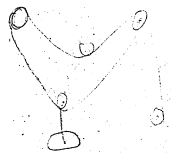
You refer the units of heat developed in the calorimeter, back to the cylinder and base your calculations upon a boiler pressure ~~given by gauge obviously incorrect~~. And even ~~were they correct there would be diminution of pressure~~ due to friction in pipes & bends, steam ports, and very little from loss of heat all of which should be passed by and the indicator springs if at all correct be considered as giving the true pressure.

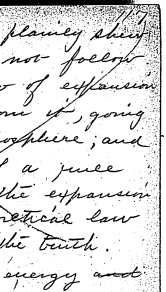
1841.487
772
3682974
12890409
12894409
1421627.564

33000)236938(7.1
231
5938

33000)272355(8.2
264
8355

1841.487
3683
1421627.564
9207435
3683974
12891409
1841487
5524461
33000)236938(7.2
231
5938
516177
4614777
3233
11793
198)2369.38(8.7
1584
7.27





~~Your indicator cards plainly show that the steam does not follow the theoretical law of expansion but is very far from it, going way below the atmosphere; and the application of a juice which supposes the expansion to follow the theoretical law will be far from the truth.~~

~~Besides, heat is energy and there is the energy~~ (directly shown in the heating of the water, namely 1,841.487 × 772 or 1421628 ft. lb. for every minute or 236938 ft. lb. per minute = 7.2 H.P. There is no reason for going behind this fact. By using a formula involving the thermo-dynamic equivalent of heat and finding the horse

continued

628.2) 1195.4108 (1.8
628.2
567.21
1195.4108
.01602

.01602) 1195.4108 (74619.9
1121.4777
7401
6408
9930
8652
3188
1602
15860
14418
14420

628.2) 16170 (25.66
1256.4
3560
3140
4160
3768
3920
3768
1520

628.2) 74619.9 (118.8
62820
11799
6282
55179
50256
4923.0

628) 20620 (3
1884
2260
1884
376

16.5
2.6
990
330
42.90

1195.4108
.0888
9788664332
10758669972
10758669972
1158238

42) 33.88 (0.8
33.6
10.88
8.4
2.48

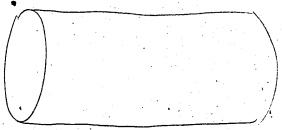
42) 1072.9 (25.54
84
23.9
21.0
2.6
2.1
0.5
0.4
0.1
0.1
0.0
1032.0

32.69
.3

1195.4108
1174.912
16.4985
2.8

1072.6
.09
96.534

1072
.09
9648
9648
106.128



.1841
.1779
.642
.772
.1329
.4634
.4634

1195.4
1145
50.4
77.2
4008.5
3585
3585
3585.0
3585
3585
3059
2390
669.0

198) 51106.4 (1195) 32.5

1000) .4640 (.000464
4000

.000464
304
18556
1392
.141056

1195.4108
.141056
1195.269744

1000) 110.0 (.11
304
11
304
304
33.44

1612
33.44
1645.44

~~1625.2~~

1000) 15.40 (.01540
1000
01540
304
616
462
4.6816

625.2
4.6816
632.8816

1000) 1.057 (.001057
1000

.001057
304
4225
317
.321328

1178.912
.321328
1178.590672

1195.269744
1178.590672
16.679072
16.6790 04
16.68

.31635 2
587269
287269
167544
174459 3 9 20 (27.566
1178 9 0 6 7 2
478833
443016
358179
164440
41733 92
37 7 7 2 4
3766 40

$$\left[\log_e\left(\frac{L}{l}\right)+1\right]\left(\frac{pl}{L}\right) = \text{Mean}$$

$$\left[\log_e\left(\frac{L}{l}\right)+1\right]\left(\frac{pl}{L}\right) \times \text{Stroke}$$

1195.27 : 1

1195.27) 1841.487 (1.54
1195.27
646.217
597635
485820

power corresponding to the amount of heat developed in calorimeter you have employed ~~if~~ that heat to raise water to steam at 25 lbs. boiler pressure and then used it in a steam engine, where we well know but a small part of the heat can be, even theoretically, returned in work. It never was proposed to convert the calorimeter into a boiler, in which steam is generated by a copper wire heated by electricity, as the same electricity would give vastly greater economy in an electro-dynamic machine. The idea

122

632.55) 16 45.44 (2.6
1265 76
379 680
379 728

Hyl. log. of 2.6 = .956 + 1 = 1.956

25
14.496
2.6) 39.4896 (15264
36 XX
26
130
69
53
176
156
200
197
3

1195.27) 16.678900 (.0139
11 95270
4726630
3585810
11404990
10751
7

15.264
1.956
91584
76320
137376
152640
29.85638 4

.139
.26
834
278
.03614

1195.27) 1178.59 (.98
10 75743
10284704

772) 31,1450 (.0403
30 88 4
2650

772
1 32
6732
2316
27832

Expended 16.95 11.53
recovered 7 +
Expended 18.65 13.28
recovered 6.8

5.35
2.56
8.22

33.52
7.5
16760
23464
23464
2597.800

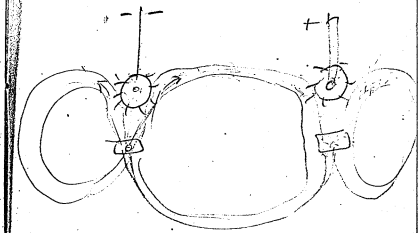
11.15
33 000
345
345
3795 000

3795 00) 25 97 800 (6.8 H.P
60
22770
32080
29160

22.8
4.15
18.65

purpose is to heat the carbon 20
top of the electric lamp.

The horse power in the 184,487 units of heat ~~that~~ have shown to be equal to 7.2 H.P.



and yet your formula shows only .63 H.P. The natural ~~inference~~ inference to be drawn from your calculations in this instance would be that .63 H.P. internal work has mysteriously produced 7.2 H.P. external

work! The same discrepancy is seen in second experiment where $\left(\frac{335197}{11.5}\right)\left(\frac{772}{33000}\right) = 6.8$ H.P. external work is produced by .599 H.P.! You have made a slight mistake in arithmetic making it .81 instead of .599.

Since in the first experiment the balance of work, as shown by indicator, which H.P. was expended in heating the wire in calorimeter was 11.53 H.P. and the amount of heat returned in calorimeter were equivalent to 7.2 H.P. the efficiency by your own data should be $\frac{7.2}{11.53} = 62\%$ and in second experiment $\frac{6.8}{13.28} = 51\%$. at the least

1072.6
115.59
965.34
75830
53630
10226
10226
123981.834

3351.97
51.192
6703.94
13407.88
33519.7
335197
1055591

10738.049.74
2178
93948.3
7307.09
10335.7
208774

375500)22245.9.22 3(5.99
1875000
3770.9.27
3775.09
35542.73

1072.6
76.7
7508.2
6435.6
10726
179 12.42

2985.4
77.2
5970.8
2097.8
2097.8
100)230472.9

13.28(6.800(.51
6640
1600
1330
2720

1072.6
1.0282
7508.2
8558.08
965.34
1058.56
16.7
7410592
6351936
1058.56
7767.95552

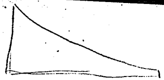
6)1768
294.6⅔
77.2
5892
2062.2
2062.2
2062.4
2.2 2 6 2.6(.69
7.08
2.99
2.7
982

1768
77.2
3536
12376
12376
13689.6

1195.27
1178.60
16.67

~~Know that in order to make them all efficient as work the steam would have to come down in temperature to zero and be doing work at the time which is impossible. even in expanding in a compound engine to one pound above vacuum which is an extreme case the pound of steam containing 1195 units would part with only 50 units and the remaining 1145 must be lost. But with our non-condensing engine the steam can do work only down to atmospheric pressure at the utmost, giving up nearly 16.7 units in work~~

132



1195
1178
17

11000000
30
33,000,000

267
213

33000
60
1,980,000

62.8.2
1612.

267
213
44

215
490
703

0711
2011

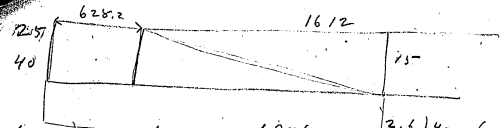
1/16

44/703

703)440(

44)703(16
44
263
264

In view of this fact then 133
every 1195 units will give only
16.7 units in work and
since by your data 1072.6 cu. ft.
=(1072.6)(.0987) = 105.8656 lbs.
passed through in 6 minutes,
Containing 1195 units per lb.
and giving up as work
16.7 units per lb. ∴ the
number of units in work
would be 1768 units in 6 m.
or 1364896 ft. lbs.
or 227483 ft. lbs. per m.
= 6.9 H.P. whereas the
Calorimeter returned 7.2 H.P.
showing undoubtedly that
the gauges were inaccu-
rate.

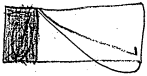


628.2) 1612.0 (2.6
25.6
35.56.0

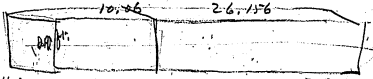
1.956
.25
9780
1956
29.340
1.5
14.34
2.6
8.0
2.8
3R.284

2.6) 40.0 (1.5
26
140
130

16



.0994) 1.0000 (10.06
994
10.06
×2.6
6036
2012
26.156

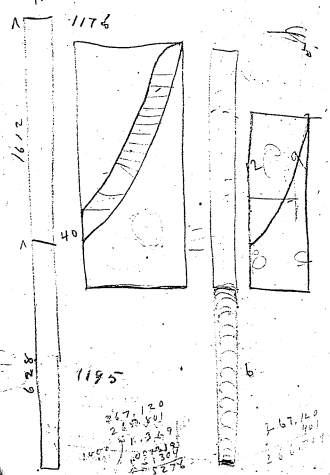


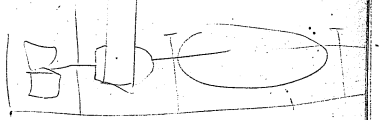
14.34
144
5736
5736
1434
206.496
26.1
123897
10324
10324
206496
123897
1129.92
5401.1
10.5856
3200
2700
4320
2700
5401
5721.79

775
16.7
5425
4650
775
129.4 2.5
2.6
7755
5850

775
25
3875
1550
1937.5
785
5812.5
123937.5
6799.10
67879
67879
96.0860 50

775
33
3875
5812.5
9529.84 (29.
66
292





1195.27 — at 25 lbs. t.p.
1178.59 — at atmosphere.
16.68

Temp. 266°.719
212°
54.719

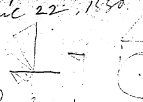
54.719
726.719

726.719 / 13 = 55.94

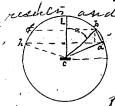
13 / 1195.27 (91.94
117
52
13
39
132
117
157
156
91

91.94
72
183.88
82.58
82.58
1977.88
1055.7
4964.96
5658.24
3548.0
70978
6 / 75144440.86
33000 / 1252407 (37
99 x
262
237
374

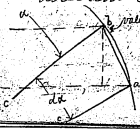
April 22, 1890. Clarke



Prof. Rowland's demonstration of power of electric light as worked out from the final results and diagram as given by him in a letter to me.



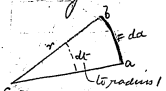
If c is the plane surface from which the light emanates and L is the power in the direction of the normal to that surface (supposing the plane c to be within a sphere so large that all points are practically at the same distance from the surface of the sphere) then the power in the direction cb would be $L \cos \alpha$.



value of light $= L \cos \alpha$.

We suppose the radius of the sphere equal to unity.

The circumference of the circle on the parallel bf is $2\pi \sin \alpha$ and if this be multiplied by arc ba corresponding to angle $d\alpha$ it will give the area of the zone.



The differential equation then gives $d\alpha = (r\,d\alpha^2 + dr^2)^{1/2}$, but $r = 1$, $d\alpha^2$ should therefore be $d\alpha^2$ and equal to $d\alpha^2$, this being a circle r is constant and therefore equal to zero, hence $d\alpha = (d\alpha^2)^{1/2}$, and $d\alpha$ is length of arc.

The area of zone is then $2\pi L \sin \alpha \cos \alpha \, d\alpha$ and for the equal zone on opposite hemisphere also we have total $4\pi L \sin \alpha \cos \alpha \, d\alpha$ which is to be integrated between

limits $\frac{\pi}{2}$ and 0 π.

Total value $= 4\pi L \int_{\frac{\pi}{2}}^{0} \sin\alpha \cos\alpha \, d\alpha$.

$\cos\alpha \, d\alpha = d.\sin\alpha$

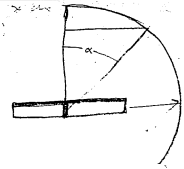
$\therefore$ Value $= 4\pi L \int_{\frac{\pi}{2}}^{0} \sin\alpha \, d.\sin\alpha$.

Integral of $\sin\alpha \, d.\sin\alpha =$

$\frac{\sin^2\alpha}{2}$ which for $\frac{\pi}{2}$ is equal to $\frac{1}{2}$, hence

Value $= 2\pi L$.

The surface of a sphere is its radius unity, equal to 4π and if light had been of same value in all directions its value would be $4\pi L$. The actual value of face is therefore one half the value perpendicular to the face, the greatest value.



The full value of the edge as shown by arrow is l and the value will be proportional to the cosine of the complement of α or to the sin of α and the formula for face value will give the value for edge

value $= 4\pi l \int_{\frac{\pi}{2}}^{0} \sin^2\alpha \, d\alpha$.

Integral of $\sin^2\alpha \, d\alpha =$

$\frac{\alpha}{2} - \frac{\sin 2\alpha}{4}$, and for the limit 0 their values will be 0 but for limit when $\alpha = \frac{\pi}{2}$ we have

$\frac{\pi}{4} - 0 = \frac{\pi}{4}$. hence

value $= 4\pi l \left(\frac{\pi}{4}\right) = \pi^2 l$,

but if the value of $\underline{l}$ had been equal in all directions it would have been, as with face, equal to $4\pi \underline{l}$ hence the actual value is $\frac{\pi}{4}$ or .7854 of the edge value. Hence having found by photometer the face and edge values we have average value in every direction equal to

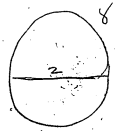
$$\frac{L}{2} + .7854\, l.$$

This supposes the value of $\underline{l}$ to be constant which would be the case with Edison's carbon loop only when a perfect circle and no separation at the bottom which of

3.14159

course is impossible.

3/0000000000

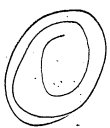


12960
2.73
38880
90720
51840
61300

$\frac{4}{1}$

$\frac{1}{1}$

775) 61300 (7
54250
7050



772) 61300 (79.4
54000
7260
6948
3120

50 to 1. 772) 3600 (7.2
5400
1900
1160.

0000

0000

0000000

965.7) 72.150 (.0747
67599
45510
35625
68820

78.98) 888.34 (
888.34) 78.9800 (.089
71 0.672
791280

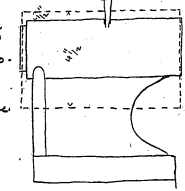
773) 55.700 (72.15
5404 ×
1560
1544
1552
3880

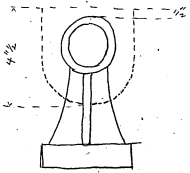
772) 61.350 (79.41
54 0 7 ×
7260
6948
3120
3088
320

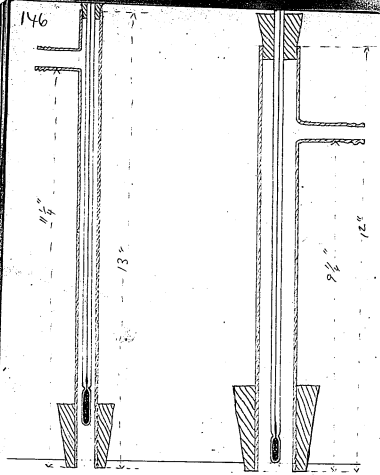
Calorimeter for pieces of block

May 1, 1880

on commutator side of Edison's dynamo-electric machine

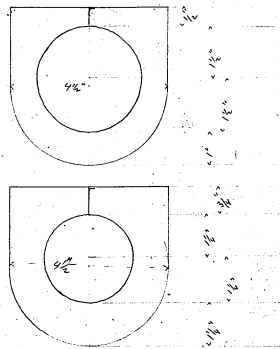






+ width of pillow block +

+ width of bushing +



May 3rd 1880.

Calorimeter Test of energy lost by friction in bearing on the commutator side of Edison's dynamo-electric machine.

The thermometers will be designated as follows.

A, the long thermometer graduated to half degrees.

B, the short thermometer graduated to even degrees.

Temperature of air at beginning of experiment by A was 75 3/4 °F.

The reading of A is greater than B by 1/4 °F. A will be taken as the standard.

1st Test for obtaining the rate of cooling or loss in the calorimeter. Dynamo not running and at temp. of air.

Time	Weight	Temp. of inflow. Thermom. B	Temp. of outflow Thermom. A.
h m s	lb oz		
2-42-30	8 - 9	98-5 °F	93- °F
2-43-30	8 - 15	98-5	95
2-44-30	9 - 6½	98-	94-75
2-45-30	9 - 14	98-	94-75
2-46-30	10 - 5½	97-75	94-6
2-47-30	10 - 13	97-5	95-75
2-48-30	11 - 4½	97-	94-5
2-49-30	11 - 11½	97-	94-3
2-50-30	12 - 3	96-8	94-2
2-51-30	12 - 10	96-5	94-1
2-52-30	13 - 1	96-3	93-9
2-53-30	13 - 7½	96-	93-9
2-54-30	13 - 15	95-8	93-5
2-55-30	14 - 6	95-6	93-3
2-56-30	14 - 12	95-	93-2

Temp. of air at end of experiment. 76 3/4 °F. by A

4 oz
1 "
2 " Marly
1 " Brace
½ " Solder

8½ oz

Dynamo not running and at Temp. of air.

Temp. of air at beginning of experiment. 77°.3 F.

by A.

2nd test for obtaining the rate of cooling or loss in the calorimeter

Time	Weight	Temp. of Inflow. Thermom. B.	Temp. of outflow Thermom. A.
~~h. m. s~~	~~lbs. oz~~		
3-28-30	5 - 8½	120-5 °F	106-5 °F
3-29-30	6 - ½	120-5	109
3-30-30	6 - 8	120-	109
3-31-30	6 - 15½	120-	110
3-32-30	7 - 6½	119-5	110-25
3-33-30	7 - 14	119-	110-50
3-34-30	8 - 5½	118-5	110-75
3-35-30	8 - 12½	118-	110-75
3-36-30	9 - 3½	117-75	110-75
3-37-30	9 - 10½	117-	110-75
3-38-30	10 - 1½	116-75	110-75
3-39-30	11 - 6½	116-25	110-75
3-40-30	12 - ½	115-50	110-75
3-41-30	12 - 8	115-	110-50
3-42-30	13 - 1	114-75	110
3-43-30	13 - 8	114-	109-75

Temp at end. 76°.5 by A.

Dynamo not running and at temp. of air.

Temp. at beginning of experiment. 76°.5 F. by A.

3rd Test –
Cold Water used instead of hot.

Time P.M. h. m. s.	Weight	Temp. of Inflow Therm B. °F	Temp. of outflow Therm A. °F
	0½ – 0		
4-6-30	5 – 13	56 – 75	73 – 5
4-7-30	6	57 –	73
4-8-30	6 – 4½	57	72 – 5
4-9-30	6 – 6	57	72
4-10-30	6 – 8½	57	71 – 5
4-11-30	6 – 11	57	71
4-12-30	6 – 14	57	70 – 5
4-13-30	7 – ½	57 – 5	70 – 25
4-14-30	7 – 3½	57 – 5	70 –
4-15-30	7 – 6	58 –	69 – 5
4-16-30	7 – 8½	58	69 – 5
4-17-30	7 – 11	58	69
4-18-30	7 – 13	58	69
4-19-30	8 –	58	68 – 75
4-20-30	8 – 2½	58	68 – 50
4-21-30	8 – 5	58	68 – 50
4-22-30	8 – 7½	58	68 – 25
4-23-30	8 – 9½	58	68 –
4-24-30	8 – 12	58	68 –
4-25-30	8 – 14½	58	68 –
4-26-30	9 – 1½	58 – 25	67 – 75
4-27-30	9 – 2½	58 – 25	67 – 75
4-28-30	9 – 5	58 – 75	67 – 50
4-29-30	9 – 7½	58 – 75	67 – 50
4-30-30	9 – 9¾	58 – 75	67 – 25
4-31-30	9 – 11½	58 – 75	67 – 25

Temp. at end (of air) by A. 76°.5

Dynamo not running and at temp. of air.

Temp. at beginning of ex. 76°.5 F by A.

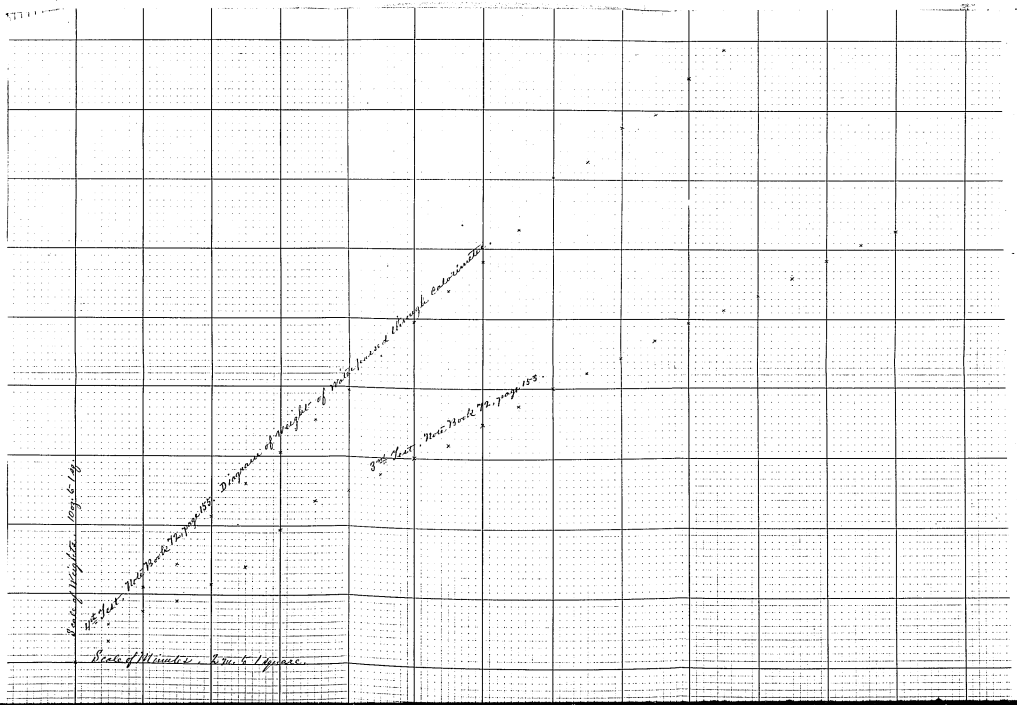
45 Test.

Warm water.

Time h. m. s.	Weight lb. oz.	Temp. of Inflow B	Temp. of Outflow A
		0F	0F
4-5-3-45	8-13	101-25	95-25
4-5-4-45	9-4 1/2	101-25	94-
4-5-5-45	9-10	101-	94-
4-5-6-45	9-13 1/4	100-75	94-
4-5-7-45	10-4 1/2	100-50	94-
4-5-8-45	10-9	100-	94-
4-5-9-45	10-13 1/2	100-	94-
5- -45	11-2 1/4	100-	94
5-1-45	11-8 1/4	99-75	93-75
5-2-45	11-13 3/4	99-75	93-75
5-3-45	12-1/2	99-	93-75
5-4-45	12-5-	99-	93-50
5-5-45	12-9 1/4	98-75	93-50
5-6-45	12-13 3/4	98-75	93-50
5-7-45	13-3 1/4	98	93-25
5-8-45	13-7 1/2	98	93-25
5-9-45	13-12 1/2	97-5	93
5-10-45	13-14 1/2	97-25	93
5-11-45	14-3 1/4	97	92-75
5-12-45	14-7 3/4	96-5	92-75

Temp. at end 76°.5 F.

[ITEM FOUND IN BOOK]



Temp. of air at beginning of test. 78 3/4°F by A.

Water in inflow at temp. of air

5th Test.

Dynamo running.

Time	Weight	Temp. of Inflow B	Temp. of Outflow A
h.m.s.	lb - oz	°F	°F
9-48-	5 - 5	73 - 5	83
9-49	6 - 5	73 - 5	81
9-50	7 - 9½	73 - 5	79 - 75
9-51	8 - 1	73 - 5	79
9-52	8 - 14	73 - 5	78 - 75
9-53	9 - 13½	73 - 5	78 - 50
9-54	10 - 10	73 - 5	78 - 50
9-55	11 - 7¾	73 - 5	79 - 25
9-56	12 - 4	73 - 75	79 - 50
9-57	12 - 15	73 - 75	79 -
9-58	13 - 10½	73 - 75	79 - 75
9-59	14 - 6	74	80 - 25
10 -	15 - ¾	74	80 - 50
10 - 1	15 - 11¼	74	80 - 75
10 - 2	16 - 5½	74	80 - 25
10 - 3	17 -	74 - 25	79 - 75

~~Temp.~~ of air at end 74 1/4°F. by A.

1.5 : 10.1 :: 10 :

1.5) 101.0 (67.3

101.265625 / 10.063

2006) 1 2656
12036

20123) 62025
60369

1/8 : 10.063 :: 10

100.63
9

8) 90.567
11.321
9.43

Broken pail 2 lbs. 7 oz
2 lbs. 5 oz

Thermometer A broken.

May 5th 1880.

1st Test beginning with machine at rest.

Temp. of air at beginning 67°.

Time	Weight	Temp. of Inflow by B.	Temp. of outflow by B
a.m. 7-5-30	2 lbs. 11 oz	68°-9 °F	69°-1 °F
7-8-30	5 lbs. 6 oz	68°-9	69°-1
7-11-30	7 lbs. 15 oz	68°-9 air 67	69°-1°
7-14-30	10 lbs. 6 oz	68°-9	69°-1
7-17-30	12 lbs. 10	68°-9	69°-1
7-20-30	14 lb 3	68°-9	69°1
7-23-30	15 10	68°-9	69°1
7-26-30	17 6	68°-9	69°1
Engine started			
7-29-30	2 - 9 5 - 3	68°-9	69°1
7-32-30	9 - 1	68°-9	69°3
7-35-30	10 - 13	68°-8	69°5
7-38-30	11 - 2	68°-8 air 68°.5	69°9
7-41-30	12 -	68°9	69°7
7-44-30	13 - 7½	68°9	69°9
7-47-30	14 - 15½	68°9	69°9
7-50-30	19 - 10	68°9	69°5

Plate

Time	Weight	Temp. of Infusion	Temp. of Decoction
	2 lb 10 oz		
7-53-30	7 – 15	69° 5	68° 9
7-56-30	12 – 5	69° 5 air 69°	68° 9
7-59-30	15 – 9	69° 5	68° 9
8-2-30	17 – 10	69° 6	68° 9
	2 lb 5 oz		
8-5-30	5 – 9	69° 8	68° 9
8-8-30	7 – 8	69° 8	68° 9
8-11-30	9 – 14	69° 8 air 69°	68° 9
8-14-30	12 – 7	69° 9	68° 9
8-17-30	14 – 12	70°	68° 9
8-20-30	16 – 15	70° air 69°	68° 9
8-23-30	19 – 6	70°	68° 9
8-26-30	21 – 12	70° air 69° 5	68° 9
	2 lb 14 oz		
8-29-30	4 – 15	70° 1	68° 9
8-32-30	7 – 3	70° 2	69°
8-35-30	9 – 7	70° 2 air 69°	69°
8-38-30	11 – 8	70° 3	69°
8-41-30	13 – 9	70° 3	69°
8-44-30	15 – 10	70° 3	69°

?12

2 775
3 3/1550
5.7
1.2
3/0.2
5.7
5.2.2

775
2
15.50
1.6
930
1550
3/24.80.0
8.27 ft-lbs per sm.

These are taken as representing the constant heat generated in friction of C

Time	Weight	Temp. of Inflow	Temp. of outflow
8-47-30	17 – 10	70°4	69°
8-50-30	2 – 9 4 – 9	70°5	69°
8-53-30	6 – 9	70°6	av 69° 69°
8-56-30	8 – 9	70°6	69°
8-59-30	10 – 9	70°6	69°
9-2-30	12 – 9	70°6	69°
9-5-30	14 – 9	70°6	69°
9-8-30	16 – 9	70°6	69°
9-11-30	18 – 8	70°6	av 69° 69°
9-14-30	20 – 8 2 – 11	70°6	69°
9-17-30	5 –	70°6	69°
9-20-30	7 – 5	70°6	69°
9-23-30	9 – 2	70°6	av 70° 69°
9-26-30	11 – 5	70°6	69°
9-29-30	13 – 12	70°6	69°

Temp. of air 71°

After water had been running through calorimeter until 2½ P.M. a test was taken with following results.

Water passed in three minutes,

2 lbs. 4 oz.

Temp. of inlet 70°.7.

Temp. of outlet 72°.5.

72.5
70.7
1.8

7757
24
1550
1554
775.4
1.8
1403.8
775.4
3 | 3157.8
1052.6 ft. lbs. per m.

Another test gave 1029 ft. lbs.

Temp. of air 70°.

But little work, a few lamps only

Time	Weight	Temp. of Inflow.	Temp. of Outflow
9-32-30	15 - 12	70°6	69°
9-35-30	17 - 12	70°7	air 70° 69°1
9-38-30	2 - 9 4 - 6	70°8	69°2
9-41-30	6 - 2	70°8	air 69°¾ 69°2
9-44-30	8 - 1	70°8	69°2
9-47-30	10 - 3	70°8	69°2
9-50-30	12 - 13	70°8	air 69°¾ 69°2
9-53-30	15 6	70°8	69°2
9-56-30			
9-59-30			

72.5
70.7
1.8

775

775
25
3875
1550
1403.8
775.4
1.8
1550.4
3875.8
3 | 3157.8
1052.6

May 6, 1880. 2 P.M.

Test by same calorimeter.

Temp. of air. 76° F.

Temp. of inflow 71°.5 F.

" " outflow 73° F

Water in one minute passed through 1.44 lbs.

772
1.44
3088
3088
772
1112.88
1.5
1668 ft. lbs.

Work being done by current.

Much work being done by current—

2nd test— 6 P.M.

3 lb 1 oz
9.5
2 lb 8 oz

Air 75°F

Temp. of inflow 72°.3 F.

Temp. of outflow 74°

1.25
772
250
875
875
965.00
1.5
6775
965
1648.25 ft. lbs.

3rd test. 8 P. M.

Air 76°F

Inflow 73°F. 3 lb. 11½

Outflow 74°F. 9

3 lb. 2½

48.15
2 96.3
16) 25.28 / 1.58
2 3 2
9 8
8 0
1 8 5

1.58
72
3 16
1106
1106
1219.76 ft. lb.

4th test. 16) 19 / 1.2
2
30

Air 75°.5 F.

Inflow 73°F

Outflow 74°.3 F

73.2
1.2
1 5 8 4
73 2
9 1 8 4
3 7 9 8
3 1 2
1190.8 ft. lb.

5th test.

Air 76°F.

Inflow 73°.7 F.

Outflow 74°.1 F.

2 lb. 2
9
11 lb. 7

1.44
72
2 8 8
1 0 0 8
1 0 0 8
1112.16
1.

1112 ft. lb.

16) 23 / 1.44
16
7 8
6 4
60

11.25
11.25
56.25
22.50
11.25
11.25
125.625

29.5
29.5

870.25
126.5625
743.6875 / 27.27

47) 343
329
542) 1468
1254
5487) 36875
34129

F. J. J.

27 1/4
13
14 1/4

1.65
.771
1.65
115.5
1.155
1.272215
.1272

John

9/12 = 37/48

48) 378 (.771
336
420
336
840

9.75
1.65
48.75
58.50
9.75
57.525

1.272 cu. ft.

The Central Station Plant.

May 8, 1880.

.771
.16
4626
771
1.2336

1.234 cu. ft.
Weight - 555 lbs.

450 lbs.
1.234
1800
1350
900
450
555.300

Cast-Iron

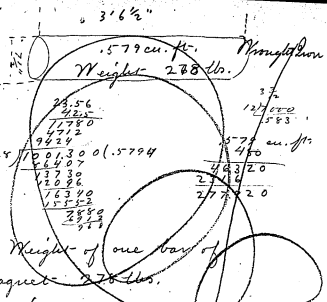
1.68
.771
168
1176
1176
1.295528

1.295 cu. ft.
Weight - 583 lbs.

1.295
450 lbs.
6475 0
5180
582.750

Total weight -

for both fields 1138 lbs.
For three magnets 3414 lbs.



28.56
9.25
1780
4712
9824

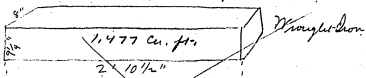
1728 | 1001300 (.5794
864 07
137 30
120 96
163 40
155 52
7888
7776
112

12 | 000
583

.579 cu. ft.
480
4632 20
2 7 7 6
277 6 20

Weight of one bar of magnet 278 lb.

Weight for three magnets 1668 lb.



9.25
74.00
34.5
370
296
222

1728 | 25538 (1.477
1728
8250
8064
1338
1209
12840
12096
744

1.477
480
118160
5908
708.960

Weight of one top bar 709 lb.

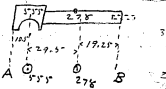
Weight of three magnets 2127 lb.

Total weight of iron in the three magnets

3414
1665
2129

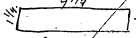
2240 | 7209 (3.2 Tons.
6720
4890
4480
4100

19.25
2.75
1400
13475
3850
53 51.50



48.75
5.55
2437 5
2437 5
2437 5
2705 6.25
53 51.50

59.25 | 32407.75 (547 lb. will be the entire
2962 5
2782 7
2370 0
4125 pressure at A for one magnet. This is distributed over a surface of 11.6 sq. in. which gives a pressure of 47 lb. per sq. in.



9.25
1.25
4625
1850
925
11.562 5

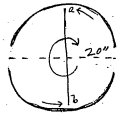
11.6 | 547 (47
464
830

555
10.5
2775
555
5825.5
1120
59.25) 18897.5 (286 lbs.
1185.0
50.875
47400
3575.0

275
40
11120

547
286
833

The weight pressing on B which is an 1½" bolt will be 286 lbs.



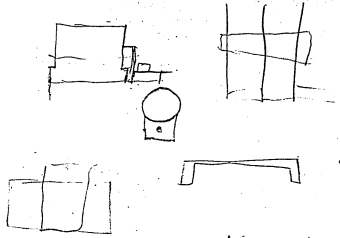
120 H.P.
33000
360000
360
39600000 ft. lbs

If it revolves at 600 per m., the circumference being 62.832, the speed at circumference will be 3142 ft. per m.

62.832
600
12/37699200
3142

and as 39600000 ft. lbs are to be exerted in this time it will require a magnetic resistance at the circumference opposing revolution equal to 1260 lbs. half of which

3142) 39600000 / 1260 or 630 lbs. is the resistance of the field at each pole.
3142XXX
8780
6284
18960
18852
1080



The rule for finding the diameter of a shaft is $d = \sqrt[3]{\frac{fWL}{T}}$. where d is the diameter, f the factor of safety, W the load of torsion, L the lever arm, T a coefficient, determined by experiment, f. be 9800 for wrought iron and 15.000 for steel.

$$d = \sqrt[3]{\frac{8 \times 1260 \times 10}{15000}} =$$

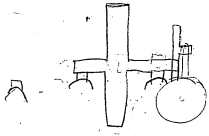
12600
8
100800

3/5.00346053
1.66782018

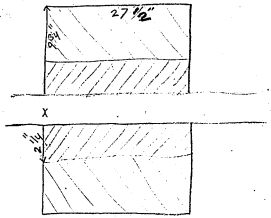
3/4.1760913
1.3920304

4.60540
24662

24662)460540 (1.88 inches diam. for
24662
218780
197296
214840
197296 shaft.



Armature



95.0625
5.0625
90
3.1416
80
282.7440

283
27.5
1415
1981
566
1728 / 7782.5 (4.5
6912
8705
8640

45
45.0
2250
180
2025.0

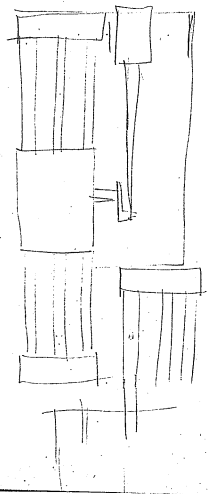
Weight of iron in armature 2025 lbs.

3.1416
19.5
28270800
25132740
31416
78.5398 / 615.4752 (.7854
5346
666
639
9216
3240
3372

3.1416
18.5
157080
251328
31416
78.5398 / 581.6328 (.7854
5346
3971
3372
599

2 (9 1/2
4 3/8

19 3/4
17 1/4
2 1/4



Questions to ask Mr. Porter.
How do you intend to provide for the lateral motion of 1/8"?
What are you going to make the dimensions of shaft and why? Weight of armature to be considered and also the tremendous strain due to the attraction of a field when the mass of the armature happens to be out-of-line, amounting to many pounds.
Sudden strain resulting from short-circuiting, very great. What will be the weight of your engine and bed with sole plate complete. What do you think of the direct supporting of the heavy weights by pillars as compared with trussing.

How about the arrangements for distributing steam, for settling the water and for returning it to the boiler?

How about head and tail arrangement of dynamo and engine and which end is to be turned toward the passage way.

Straight side for commutator pillow block.

Use two pillow blocks only. Do you not only make your shafting strong enough for torsion but also much larger to render it perfectly stiff? How about placing the dynamo above the boilers on account of heat?

How about the armature

in a ferrule which is keyed to the shaft?

How about trapping the steam and does the steam in jacket flow through or is it condensed there and returned to boiler?

Do you prefer to use the Babbitt metal in bearings and for what reason?

What would be the effect if dynamo is running free at free speed and current is instantly put on?

The inside pillow block on commutator side must be capable of removal.

Mistake in book on page 117.

1860
.22
3720
3720
409.20

1662
2234
3894 lb. cast-iron
.184
$15.5776

38
316
3800
114
117.80
34
316
.10
15

3105
2160
5265 lb. forging
.05
$263.40

800 lb. copper
555 lb. copper
.33
2220
1665
$188.70

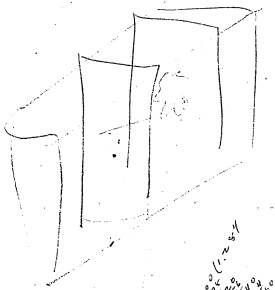
200 lb. brass
.30
$60.00

218)450($2.06
218
200

957
380
1367 lb. zinc
.09
6
$136.7
60.
188.
263.
156.
$803
.60 Soapstone
~~300 Stator~~
409 Thin Plate
~~114~~ Copper in armature
$1690

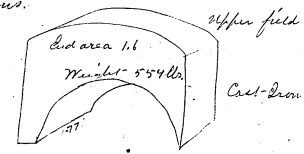
700) 3600 (5.
2800
700) 800 ($8.40
560
300
9) $15.20
$1.77

)75000



75) 1200 (1.60
75
450
450

Calculation of weights of dynamo - for cruise station based upon completed plans.

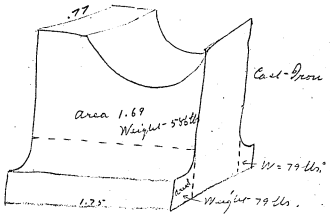


1.6
.77
112
112
1.232
450 lbs.
6 1600
4928
554400

Weight of one field 554 lbs.

Weight of 3, 1662 lbs.

1662
2232
3894



1.69
.77
1183
1183
1301.3
450
585650
5265.2
5865.50
1.58
744

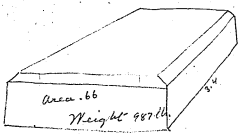
1.75
.45
875
700
787.50
787.50

Weight of one field 744 lbs.

Weight of 3, 2232 lbs.

2.4
.31
7.44
32
477) 7.44
.77
2.30

4.26
.66

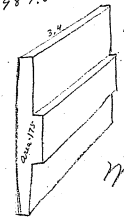


Zinc base,

3.4
.66
204
204
2.2 44
4.40
88760
88760
987.360

Weight of Zinc base under field.

987 lbs. See page 193.

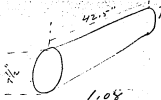


Brass plate for field.

1.75
3.4
700
525
5.95 0
5.04
2380
2975
2975.80

Weight of brass plate

300 lbs.



Wrought-Iron

44.18
4.215
22090
8836
17672

1.04
4.80
8640
432
5.18.40

1728 / 18776.5 (1.08
1728
14965

Weight of one core

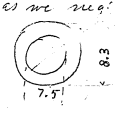
518 lbs.

Weight of 6,

3108 lbs.

This is wound with three coils of No. .10 wire (.134 diam).

If we suppose the diam. of the core to be increased by 6 × .134 and find the contents of the coil ferrule it will be approximately correct as we neglect the cotton covering.



68.89
56.25
4 / 12.64
3.16

3.1416
12.64
1256
126
3.1416
4 / 39.7098
9.9275

39.71
42.5
19855
7942
15884
1728) 168776 (9.77
15552
13225
12096
11516
1116

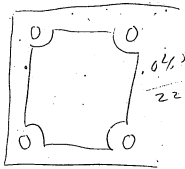
4 2.5
9.93

4 (9.77
.244

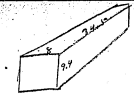
.244
548
1952
876
1828
133.712 lbs

Weight of copper wire for 6 coils.

804 lbs.



.04.5
5000
225.000



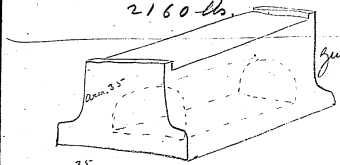
Weight of 3 75.4
9.4
75.2
34.5
3760
3098
2254

1728) 2594.40 (1.5
1728
8664
8640

1.5
4320
1200
6.0
7200 lbs.

And for 3 magnets

2160 lbs.



.35
.35
175
105
.8240
35000
35000
385.000

Weight of Brick base

385 lbs.

1662
2232
300
3108
804
2160
10266 lbs. air iron, brass, copper wire
798
385
2240) 11449 lbs. including zinc bases.
11200 5.1 tons.
2490

5.6
300
1680.0
7811.4
6526.8
1688.4

5.5-4
41.7
38778
2276
2803.5
3
7811.4

3108
21
3108
6216
6528.8

804
21
804
1608
1688.4

4.7) 17706.6 (3768
141 ×
360
329
276
252
346

3768
2232
6000
798
6798

2106
2160
4266
385
4651

1662
300
3108
804
5874
3768
2106

Weight on Innative Zinc

Weight on blue zinc

Total

with zinc. 5.1 tons.

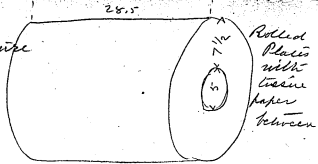
Sum of areas .35 sq. in

1.2
.35
60
36
.42 sq. ft.
440
1680
168
189.80 lbs.

987 - 189 = 798 lbs

Weight of field base.

Armature

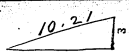


Rolled Paper with insulation paper between

314.16
19.64
294.152
28.5
1472280
2356616
589304
1728 / 8393.820 (4.86 cu. ft.
6912 ×
1851 8
1382 4
994 2
864 0
1302
450
24300
1944
2187.00 lbs.

Weight of armature iron 2187 lbs. plus 300 lbs. of copper, total weight 2487 lbs.

without shaft.



.737335
60
44.24016
6 1/3
2654406
147467
2801873

95.0625
9
104.0625 (10.209
202) 406
406
2040) 225.00
10.86
10.86
6516
8688
10.86
117.9396
2801873
2358
9432
2358
2753.76 / 3303.55 (12
2753.76 ×
549798
550752

120

500

408
10

10) .408 (.0408
80

1/5

500) 2.04 (.408
200
400

120
2
240

1240

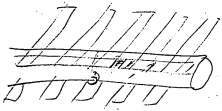
305
60
3050
9150
610.50
610.5
6106.5
6106.5

1 / 154585
10919

5 / 86944
17399

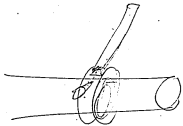
9 / 48233

249.8 lbs. pressure
400°.7 Temp.
Units in Water 406.912
Latent units 829.258
Total in Steam 1236.
Weight of cu. ft. .509



120.3 lbs. pressure
Temp 349°.95
Units in Water 354.05
Latent units 866.6
Total in Steam 1220.68
Wgt of cu. ft. .304

Pressure 14.696 lbs.
Temp. 212°
Units in Water 212.9
Latent units 965.7
Total units 1178.6



$P \propto \frac{1}{V}$

$P = c\frac{1}{V}$

$PV = c$

2)10(.5

5)120
24

10

10)240
24

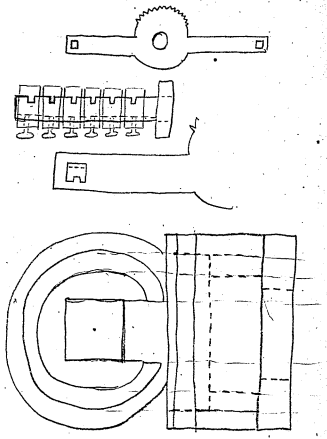
log 1.609
1
2.609
24
10436
5218
62.516 Cu. ft. .304

log 2.303
1
3.303
24
13212
6606
79.272 Cu. ft. .509

.255

1221
.304
4884
3663
371.554
6.26
22226
742
22226
2322.46

1236
.255
6180
6180
2472
315.180
79.3
945
2535
2205
249 79.5



370.0045
32
338.0045
.305
1690225
1014135
103,103225

1091.7
1194.5037
32
1226.5037
772
1.25
3860
772
381060

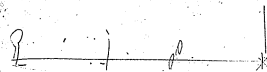
320.821
32
88.821

385.671
32
353.671
.305
1768355
1061013
107.8696555

1091.7
32.
1231.5

.695
.180
55600
695
125.100

1091.7
125.1
966.6



$x : a^2 :: x - z : z^2$

$z^2 x = a^2 x - a^2 z$

$x(z^2 - z) = a^2 z$

$x = \frac{a^2 z}{a^2 - z^2}$

$\frac{z(80)^2}{6}$

62.4
62.4
24.96
12.48
3744
3873.76
968.44

111.5
111.5
557.5
111.5
111.5
12433.25 / 149.6
1495
2938
2989
3873.75

111.5
50
31.5

31.5
31.5
157.5
31.5
945

111.5
50
31.5

50
6214
17.6

2 / 799.2.25 / 799.12

.04
.04
.66

.11
.13
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.22
7704
.02
.92
.62
.62

.56
.56
.56

.5210'

.1400'

.0.58
.8
.521

70711
14142

42426
14142

43284
14142

44721
14142

45826
14142

48990
14142

46904
14142

45426
14142

58310
14142

59161
14142
55628
14142

70711
20
84883 / 6568.80 (66.7
509.168
565200
509.165
550.3.2

51962
14142
52920
14142

53852
14142

55678
50
698820 / 44556240 (63.8
41892.20
2663000
2095960
3552800
50
3.5858 / 3552800 (111.5
3552800
41720
35858
55560
35858
197620
177290
18.

a = 17, x = 59.6
a = 18, x = 60
a = 19, x = 60.4
a = 20, x = 60.8
a = 21, x = 61.1
a = 22, x = 61.5
a = 23, x = 61.8
a = 24, x = 62.1
a = 25, x = 62.4
a = 26, x = 62.6
a = 27, x = 62.9
a = 28, x = 63.1
a = 29, x = 63.4
a = 30, x = 63.6
a = 31, x = 63.8
a = 32, x = 64.
a = 33, x = 64.2
a = 34, x = 64.4
a = 35, x = 64.6
a = 50, x = 66.7

145 29
.15
145
29
30)4.35
.145
.0175
725
1015
145
.0025375 <

.0023625 <

13.5
.15
675
135
30)2.025
.0675
.0175
3375
4725
675
.00118125 <

25
.15
125
25
30)3.75
.125
.0175
625
875
125
.0021875 <

26
.15
130
26
30)3.90
.13
.0175
65
91
13
.002275 <

.0021875 <

.002275 <

.0175
.15
875
175
.002625 <

25.5
.15
1275
255
30)3.825
.1275
.0175
6375
8925
1275
.00223125 <

27.7
.15
1385
277
30)4.155
.1385
.0175
6925
9695
1385
.00242375 <

31
.15
155
31
30)4.65
.155
.0175
775
1085
155
.0027125 <

.0027125
.00242375
.002625
.002275
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.00223125
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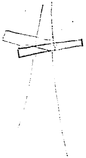
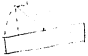
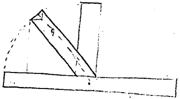
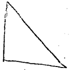
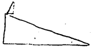
2
.0500575









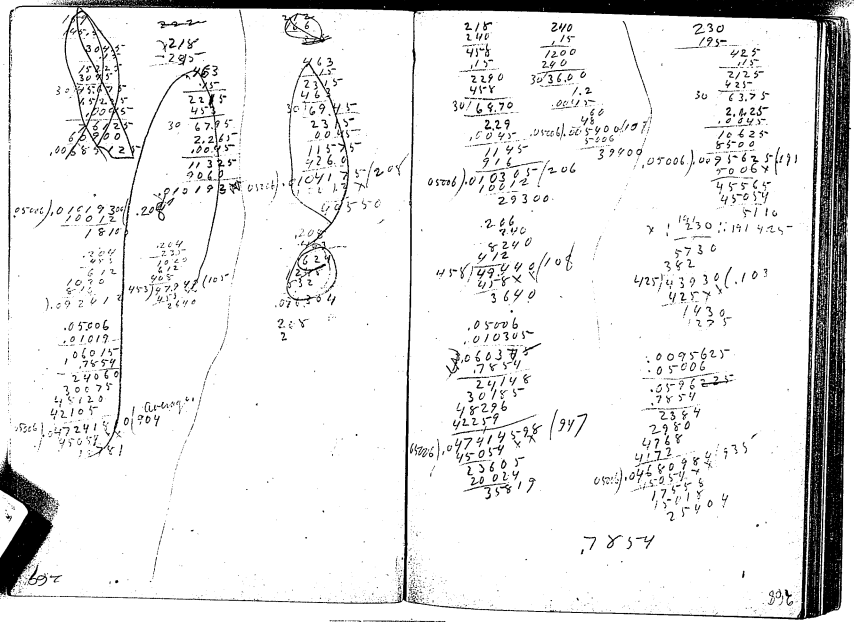


273

272

area of edge

Average .951



210
163
373
.15
1865
373
30) 55.95
1.865
.00495
93.25
7460
.05706) .00539225 (.168
5006
3386
30036
352250
168
210
1680
336
373) 33.5250 (.95
1710
1865
.00539225
.05006
.05486
7834
23380
29225
46760
45915
.05706) .0957906630 (.917
45054
52526
5006
3520

185
129
314
.15
1570
314
30) 47.10
1.570
.00495
785
628
.05706) .0070695 (.141
5006
20590
20140
1950
.0070695
.05006
.0486792 (.896
40045
48219
45054
3165

164
108
272
.15
1360
272
30) 40.80
1.36
.00495
680
544
.05706) .006120 (.122
5006
1140
1006
1280
164
108
328
164
272) 20.08 (.74
1904
9680
.006120
.05006
.05618
7854
22472
28090
44944
39326
.05706) .0491237272 (.861
40045
40757
40045
7697

163
100
263
.15
1315
263
30) 39.45
1.315
.00495
6575
5266
.05706) .0089175 (.116
5006
91390
163
.15
7304
163
263) 18.23 (.73
1841
9224
7363
1350
.00589175
.05006
.05589
7854
22392
27990
47784
39186
.05706) .0093566692 (.164
40045
33486
35042
41449

223
232
455
135
2275
455
30)16825
2275
.00455
11375
9100

05006).0102375 (204
10212
225550
20024
25

223
204
592
446
455)44592 (~~204~~
41005 × 100
4092
4004
3370
3325

.0102375
.05006
.06038 ~~225~~
.78558
24112
30055
4824
42221
05006).047335962 (946
45054 × ×
230556
200224
30322

200
222
422
.135
2220
6220
30)6330
211
.00455
.00455
8884
4440
4440
48420

199
200
422)35000 (90
3798
20

.0094995
.05006
.0595568
.78554
23824
29780
47648
41692
05006).0477892 4 (0934
5005 ×
4748
45054
17244
15015
22260

167
203
370
185
185
37
30)5555
185
.00455
925
740
05006).008325 (166
50006
33190
30030
31540

167
166
1002
1002
167
370)27722 (75
2590
1822
1850

.008325
.05006
.058389 ~~95~~
.78554
23356
29195
46712
40873
05006).045859506 (916
45054 × ×
80055
50006
30490

130
178
308
135
15540
308
30)4620
1554
.00455
730
616
05006).006930 (138
50006
19240
15015
42220
40045
130
130
1140
135
305)17940 (58
1540
2540
2440

.00693
.05006
.05699
.78554
22796
28995
45592
39893
05006).044759946 (894
40045 × ×
47119
45054
20655

119
159
278
.15
1390
278
.30 41.70
139
.00445
695
556
.05006) .006255 (125
5006
12490
10012
24780

119
125
595
238
119
278) 14875 (54
1390
9375
5304
741
.006255
.050006
.05006) .056222 (1
.78554
224885
281110
449776
393354
.05006) .441555158 (882
400445
410710
400445
10238

125
80
278) 12500 (45
11127
1300

104
156
260
15
1500
260
3) 39.00
13
.00535
65
52
.05006) .005850 (117
5006
84490
5006
393440
104
117
728
104
156
260) 12165 (47
1040
17685
1560
208
.005850
.050006
.05556
.78554
22336
27954
44772
39113
.05006) .043903856 (877
400445
385558
350445
35116

937
946
934
916
894
852
877
947
935
917
856
851
878
13) 11854 (912
117
15
13
24
26

010305
.020305
2) 020425
01027

.0095-6
.009495
.018015
00833

.00707
.00693
2) 08400
00700

1000
211
12111
.78554
44844
60555
96888
8477
951.

1000
994
878
858
872
462
211
7) 5486
.741

00833
00833
2) 016672
00836

.00612
.00622
00619

00592
00595
2) 01177
00589

3.1416
5.1
3.1416
2260
157080
150.2216

5.1
5.1
5.1
2.5.1
260

3,1416
2601
3,1416
188496
62832
8171.3016

$dA = y\,dx$

$dA = \frac{y\,dy}{\sin x}$

45.0 · 700

$y = \cos x$

$dy = \sin x\,dx$

$dx = \frac{dy}{\sin x}$

1.00000
.996
.985
.966
.940
.906
.866
.819
.766
.707
.643
.573
.500
.423
.342
.259
.174
.087
0

3,1416
2
4 | 6.2832
1.5708

19 | 11.951
11 1 88
557
57

1.0000000
.9999989
.9999958
.9999905
.9999831

1,0000000
.9961947
.9848078
.9659258
.9396926
.9063078
.8660254
.8191520
.7660444
.7071068
.6427876
.5735764
.5000000
.4226183
.3420201
.2588190
.1736482
.0871557

19) 11.9518826 (
114
55
35
174
19
88
36
122

$y = \cos x$

$dA = y\,dx$

$dA = \cos x\,dx = 2 \cdot \sin x$

$\int_{x=0}^{x=1.5708} dA = \sin 1.5708 - \sin 0$

$= 1$

1,5708 / 1.00000 (

90 / 1.00000 (.01111111

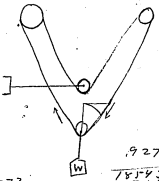
90
100

1.5708 / 1.00000 (.636618

94248
57520
57124
103960
94248
97120
94248
28720
15708
13012
12564

5664
12
67968
20.44
67968
67968
611712
6126 59695

$P = \frac{W}{2\cos\phi}$



314159
38
2513272
942477
111.262 | 119.3982 42 (1.073
111.262 ×
5 11842
77 5834
3 30080

.927184
12
1 5 5 8 3 6 8
927184
11 126208

1880
2.073
5640
131760
1880
2017.240
27.15
1005620
201724
1 47 1068
403448
5476 8066

2017.24
39.25
1005620
403448
806896
60517 2
6 0 9 0 4 7

136.24
2281
13 62
10896
2724
2724
3 1 0 3 6 762

691) 6120 (88.6
5528
5920
5528
3920

9991.2
911.32
2782.63
411.315
752
82 6130
205 7535
2892 2 63
3 1 0 5 2 7
5 5 2 6 0 7
3 3 7 4 8 3
3 1 0 6 9
5 3 2 7 7 1 0 3 7

752) 2254 (3.0332
2256
2500
2256
2440
2256
1840

.0606
629
5454
1212
3636

05-006) 381174 (761
3 5 0 4 2 ×
3 6 7 5 4
3 0 0 3 6
7 1 8 0

06637
629
54333
12074
36222

05-006) 3767 7 3 (7 5 8
3 5 0 4 2 ×
2 9 3 0 7
2 5 0 3 6
4 2 7 7 3

.05996
629
53 6 4
1192
35 7 6

05-006) 37488 4 (749
3 5 0 4 2 ×
2 9 9 6 4
2 0 0 2 4
9 4 4 0 0

2281
752

5664
1880

05-006) 5277 3 (7 6
4

05-006) 3676 5 0 5 (7 3 4
3 5 0 4 2 ×
7 2 3 0
3 5 0 1 8
2 2 1 2 5

05-713
629
5 9 4 1 7
1192 6
9 4 2 7 8

05-006) 35 9 3 4 7 7 (7 1 8
3 5 0 4 2 ×
8 9 2 7
5 0 0 6
3 9 2 1 7

1880) 5664 (3.013
5640
2400
1880
5 2 0 0

05618
629
50562
11236
33708
5006) 353372 2 (706
310424
29522

3.14161/6
3 1/6
94248
5236
9.9484

05598
629
50382
11196
33588
5006) 3521142 (703
310642
16942

703
705
718
734
749
758
761
5129
733

22,63
5,71
197,20
29,04
168,46
2,53
1,71
,07
172,77

54,25
5,84
21700
43400
26125
306.8200 [illegible]
.0022
61364
61364
.675004

3.14159
3 1/2
9.42477
52360
.927184) 9.948370 (10
927184
676530

1.079
16
6474
1079
17.264) 168

.927184) 9.948370 (10.729
927184
6765300
6490288
2750120
1854368
8957520
6

.000
.017
033 - .9271) .99484
052
070
.927184) 9.948400 (10.72993
087
927184
105
6765600
122
6490288
139
2753120
156
1854368
174
8987520
191
8344656
208
6428640
225
5563104
242
8655360
259
8344656
276
3107040
292
309
326
342
358
375
391
407
423
438
454
469
485
500
515
530
545
559
574
588
11235

602
615
629
643
656
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682
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777
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798
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875
883
891
899
906
914
13208

921
927
934
940
946
951
953
961
965
970
974
978
982
985
988
990
993
995
996
998
999
999
999
1
23335
11233
9) 47778

36 2 6 2 7

1009 9 3 4

339 8 9 2

109 9 4 40

70 2 9 15

70 1 4 6 6

81 3 8 8 8

29 4 8 5 2

5 5778394

642

.0000
.052
.105
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.995
.998
1.000

30 1.9595

653 2

2 3.1415927

1.5707964

4570

6301

8724

9595

25-2

1.5707964 / 1.000000000 / .63662
94247784

27.15
1.884
277200
27120
2715
51042
10.7297
357284
455378
102084
357284
51042
5776650874

575522160
471238920
103982680
94247784
7734896
94247784
3101176

5618
6366
33708
337708
16854
33708
1016 / 31764188 (714
33042 ×7
7221
7106
22158
1000

1.8038666

7824726
5863392
8868484 — 771.

7808212
5846878
8851970 768

7752463
5791129
8796221 758

7667845
5706511
8711603 743

7568642
5607308
8612900 727

7495817
5534483
8539575 714

7480329
5518995
8524087 7 / 5193 712

742

994.2
771.75
2/222.45
111.325
3.83
889800
33 36 75
111 325
372 75
1538.6
172
30772
107702
15386
264649
10.73
2939968377
264649
10.7287
185 25 43
238184 1
529298
185 25 43
264649
2639604 3
14566.5
44.25
7283 25
891330
582660
582660
6445681.625
7.35
3867908
8924
3159
1053
14566.05

5-1042) 5-47666 (10.73
5-1042
372460
372284
151660
102084
495760

264649
10.73
2939947
185 25 43
264649
2639968377

264649) 2 8446 50 (10.7
2 6 46 49
1981100
185 25 43
1285570

168) 1053-1046
1008
451
336
1150
1008
1424
1424

994.2
771.75
2/222.45
111.325
3.83
889800
33 36 75
111 325
372 75
1538.6
172
30772
107702
15386
264649
10.73
2939
185 25 43
264649
2.72
2715
1850
217200
27720
2715
51042

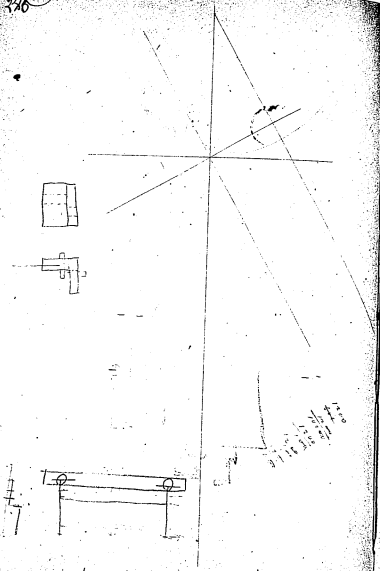
1.072
64774
1073
172.49
17249
1035 84
1053
473.83

3/4" vacuum,

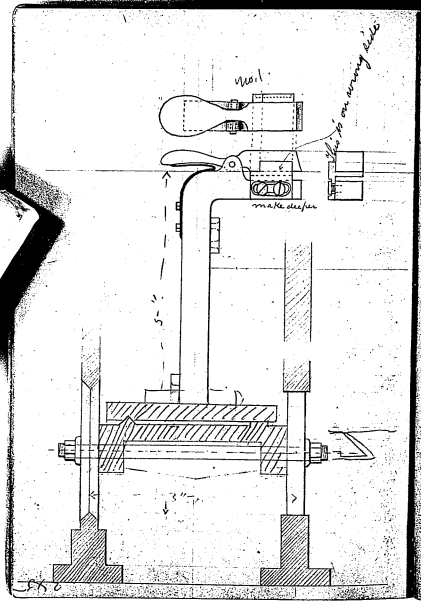
even at 120°,

~~220°~~ at 200°

994.2
911.57
2/82.43
41.315
82630
206575
2892.05
3/069
10.7297
217483
279621
62138
217483
3/069
53336107



Mr Barnes


wool
file to run nearly flat
make deeper
5"
3"

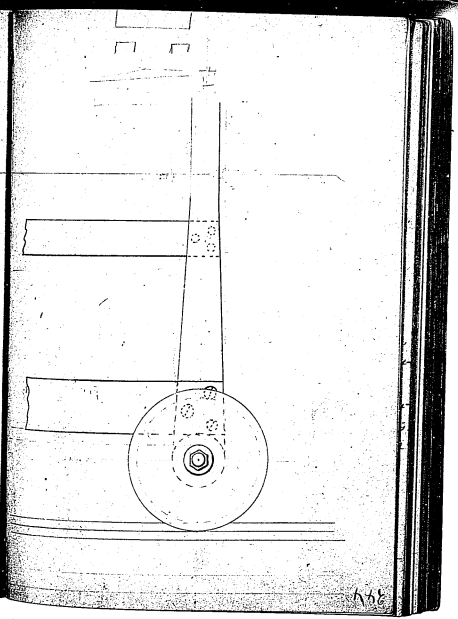
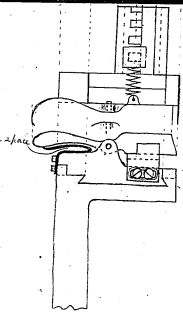
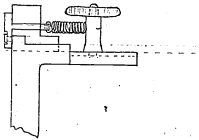
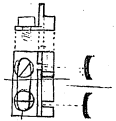
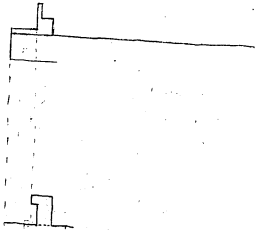


Fig. 1.


Stirrup to prevent
from coming out
of groove.
Yellow space







.047
.0325
.0145

.102
.011
.0455

.079
.034
.045

.079
.034
.045

Plates
gauge

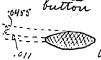
239

March 31, 1880

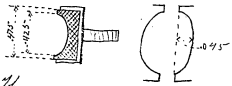
Notes on telephone.

S. H. Short.

Average diameter of Carbon button .425 inches.

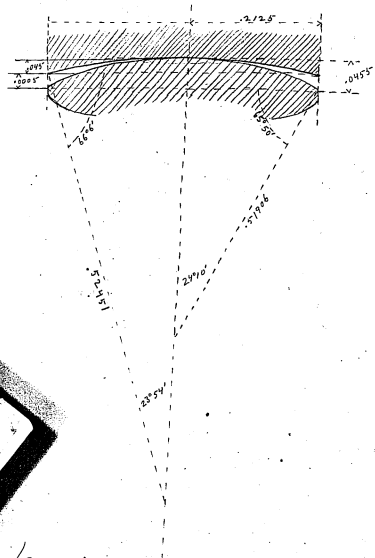


Thickness in center .102 inches.
Average thickness on edge .011 inches.



The measurements of the lens were carefully made with a Brown & Sharpe wire gauge. The cup was measured in the same manner by means of a wax cast, the wax, covered with tissue paper being firmly pressed into the cup. The results are the of several measurements most of which were exactly alike.

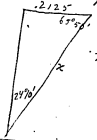
238



.2125").0455000 (.214118
92500
3000
87500
85500
2000
1925
3750
2125
16250
12875
1375

77°55'
12° 5'
65° 50'

90°
65°50'
24° 10'



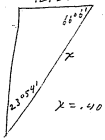
x : 1 :: .2125" : .4093923

x = .4093923). 2125000000 (.519906
2093923 51
7803850
4093923
3709927 70
3683538 07
2539 63000

.2125").0455000 (.211765
42500
2500
2125
3750
2125
16250
12875
13750
12750
10000
8500
1500

78° 3'
12° 57'
66° 6'

90°
66° 6'
23° 54'



x = .4051416) .2125 0000 (.52457
2025 7080
8829200
6202832
1726 3680
1620 5664
20580160
20257080
323 0800

9657.7
772
19314
67599
67599
7455204

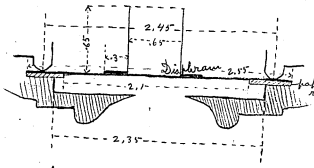
Hot 2
1644
.03797
11508
14796
11508
9332
62422 68

.03797) 1.00000 (26.3
75895
29660
22782
12780

1.644) 1.00000 (60.827
98664
13600
13704
4980
3286
17920
11508
6412

1 .21183) 1.00000 (4.7
84732
15268

Short Telephone in Section.



Mr. Shaw assumes that, the diaphram being firmly held at the edge, it is of the nature of a beam firmly fixed at both ends.

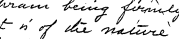
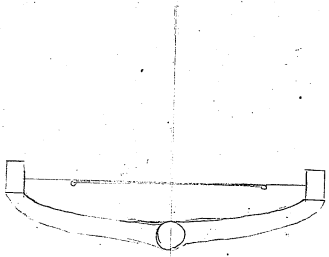
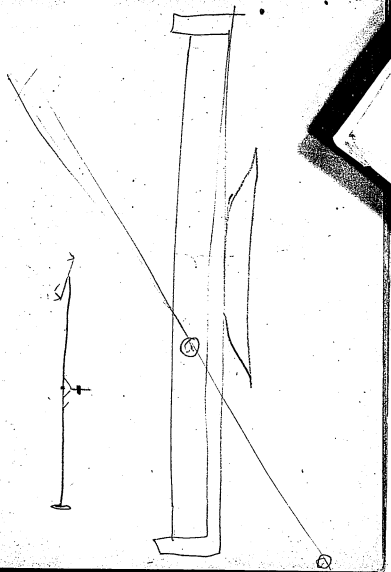


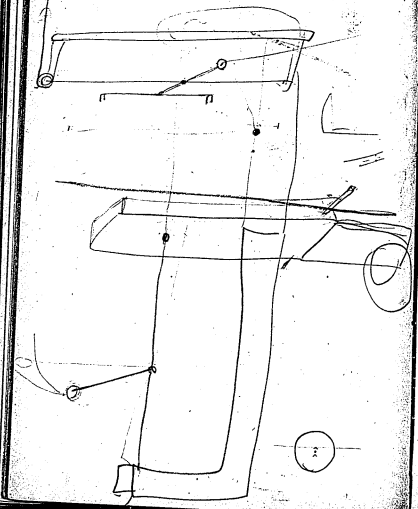
Fig. A.

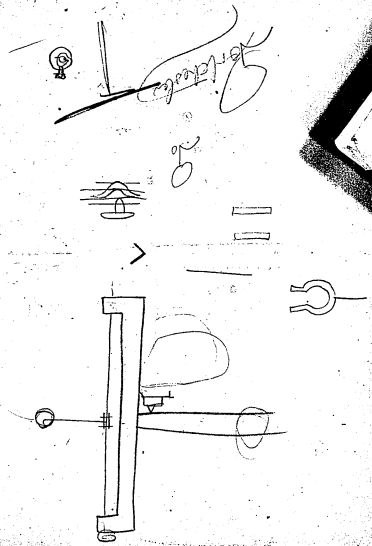
When it is uniformly loaded the points of contrary flexure are as shown in fig. A.

When the load is in the center, which is practically the case with the telephone as the mouth piece protects all excepting the center from the sound waves, the





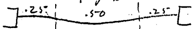




1229
2
238

relative position of the points of inflection are as shown in fig. B.

Fig. B.

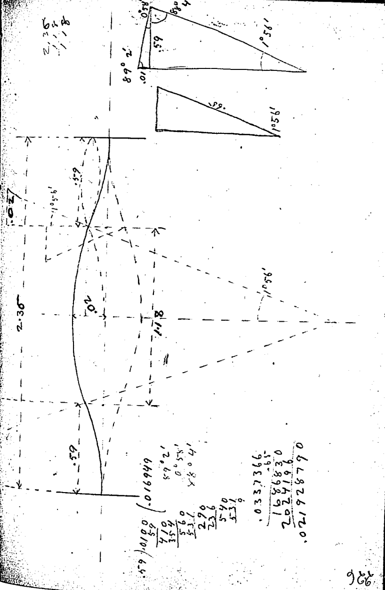


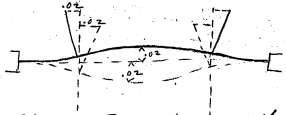
This is assumed to be the case in the following investigation.

Mr. Short states that by placing

the arms which hold the cups at the points of contrary flexure he gets more motion at the carbon button than he would from direct motion at the center of the diaphragm.

I assume that the diameter of the diaphram begins with the edge of the wooden frame and is 2.36 inches ~~by~~ measurement. The height to the center of the cups is .65. It is also assumed that the cup supports are in the most favorable position, that is at the points of flexure





which actually is not the case. The result is exactly the same as for direct motion of the center of the diaphram.

As the supporting arms are actually placed in the telephone which I examined, they are not so favorable to motion. The feet which are wide complicate matters as also the solder and heat from soldering.

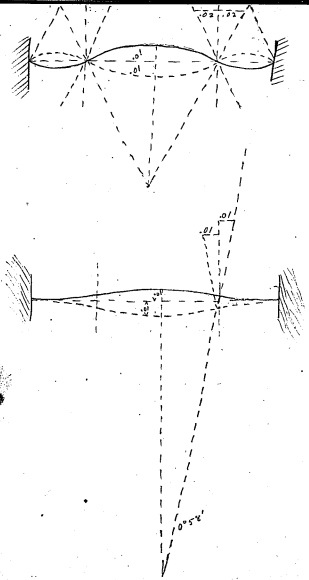
I find that when the arms are placed the ferrotype is raised as shown which makes the action uncertain.

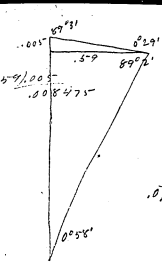
By making the arms

longer the motion would be greater, or less with shorter arms, but longer arms would interfere with quick action on account of inertia of parts.

This arrangement is a positive disadvantage as it gives no gain in motion and complicates the parts, besides necessarily being more sluggish than direct center-diaphram motion.

By experiments, April 2, 1880, I find that the analogy of the beam fixed at both ends is in no respect correct but ~~that~~ the diaphram vibrates in such a manner as to form nodes, part of the surface being on one side and part on the other of a straight line joining the circumference at opposite points.





90°
0°29'
89°31'
89°31'
0°29'
89° 2'
90°
89°2'
0°58'

.0168707
.125
843535
10122424
.0109635955

Experiments were made, April 2, 1880 with a ferrotype diaphram and the following were the shapes.

High falsetto
Diaphram lovely held.
Clarke.

High falsetto,
and very loud.
Diaphram lovely held.
Clarke.

High falsetto,
Diaphram loosely held.
Lawson.

Gruff falsetto and tremulo.
Lawson.
Diaphram loosely held,

High clear tone,
Diaphram loosely held,
Clarke.

Middle register
Diaphram firmly held,
Clarke,

The diagrams showing the positions which the sand assumed under the different sounds show that this theory

of the arms being in the most advantageous position is wrong and in fact a theory which would answer for one note would be altogether wrong for a different note, and, as far as my experiments show, not only the pitch, but the quality has a great deal to do with the form of vibrations. One important fact was ascertained namely, that the center was always one of the most active centers of vibration.

The length of a sound wave in low D is $\frac{1118}{288} = 3.88$ ft. = 46.56 in.

288)1118(3.88
864
2540
2304
2360

One cubic foot of air at 60°F weigh .0765 lbs and one sq. inch in section of this sound wave would weigh

$\frac{46.56 \times .0765}{1728} = .00206$ lbs.

If we suppose the amplitude of the vibrations to be 1/4 inch which is a most unusual case the weight of one sq. inch of air of that length would be

$\frac{.25 \times .0765}{1728} =$

.0765
.25
3825
1530
1728)19125(.0000112 lbs and the

1728 X
1840
1728
11170

$\frac{.0000112 \times (1118)^2}{2} =$ .7 ft. lbs. per second.

1118
1118
8944
1118
1118
1118
1249924
.0000112
2499848
1249924
1249924
1399 1488

That is .7 ft. lbs Kinetic energy is equivalent to .00136 lbs potential energy on each sq. in.

If we then suppose the mouth-piece to be taken away leaving the diaphram unprotected the Kinetic energy on the entire diaphram expressed in potential energy will be

.00136
3 6
8 16
1024)1400(.001 36
3 072
3 072
6 720

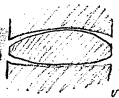
energy will be in each sq. inch

$\frac{.0000112 \times (1118)^2}{2} =$ .7 ft. lbs. per second.

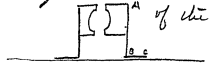
the diaphragm. This investigation has given to the Short-Telephone every advantage as to premises upon which the calculations have been made and we come out with the result that at the utmost the pressure on the diaphragm will be .096 lbs. or 1.54 ozs. and with this pressure

96
100
5
26
1.536

laying aside the fact that it is many times greater than the pressure of most sound waves, he expects to obtain more surface contact by pressure upon the lens-shaped carbon, and made of hard gas-carbon



I have omitted the consideration of the great loss in even this calculated pressure through the lever arms ABC



of the cup-supports,

I find by several careful experiments with pressure upon gas-carbon that no perceptible alteration can be seen with a pressure with the wire gauge of at least several pounds and that it takes the full man-power to compress it to the extent of two thousandths of an inch and how even the play of only five ten-thousandths of an inch in Mr. Short's lens-carbon is to be utilized is difficult to see.

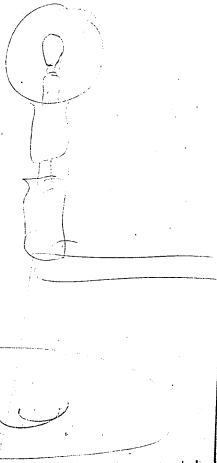
It can only be, not by changing the amount

of surface, so called, in contact; but by more or less intimate contact by pressure within the limits already in so called contact, which is the essential principal of the Edison Telephones

$$\varphi = \frac{dv}{dt} \qquad v = \frac{ds}{dt}$$

$$dt = \frac{ds}{v}, \qquad \varphi = \frac{v\,dv}{ds},$$

$$\varphi\,ds = v\,dv, \qquad \varphi s = \frac{v^2}{2}$$

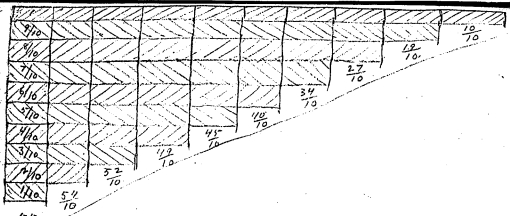


2.10

1	2	3	4	5	6	7	8	9	10
$\frac{1}{10}$	$\frac{1}{45}$	$\frac{3}{80}$	$\frac{2}{21}$	$\frac{1}{12}$	$\frac{2}{15}$	$\frac{7}{40}$	$\frac{4}{15}$	$\frac{9}{20}$	1

2520, 560, 945, 2400, 2100, 3360,

10/10, 45, 80, 21, 12, 15, 40, 15, 20
15 1, 45, 8, 7, 12, 15, 4, 15, 2
4/1, 3, 8, 21, 12, 1, 4, 1, 2
3/1, 3, 2, 21, 3, 1, 1, 1, 2
2/1, 1, 2, 7, 1, 1, 1, 1, 2
1, 1, 1, 7, 1, 1, 1, 1, 1



Total areas $\frac{55}{10}$

Resistance $\frac{10}{55}$	$\frac{10}{54}$	$\frac{10}{52}$	$\frac{10}{49}$	$\frac{10}{45}$	$\frac{10}{40}$	$\frac{10}{34}$	$\frac{10}{27}$	$\frac{10}{18}$	$\frac{10}{10}$
$\frac{10}{55}$									

$$10.6\left(\frac{520}{102000}\right) + 10.6\left(\frac{570}{85000}\right) + 10.6\left(\frac{244}{68000}\right)$$

$$+ 10.6\left(\frac{366}{51000}\right) + 10.6\left(\frac{366}{34000}\right) + 10.6\left(\frac{126}{17000}\right).$$

5200
6440
3660
7320
13980
7560
42000) 41560
10.6
249360
41560
102000) 440560 (4.3
408
520
29

415560
19200
193200
36) 779760
10.6
779760
779760
102000) 8277 (8.3
816
36) 8.3 (2.3
7.2
1.0
1.0

520.0
105000

2) 6, 5, 4, 3, 2, 1
3) 3, 5, 2, 3, 1
1, 5, 2, 1

3200
6440
3660
7320
10980
7560
41560
249360
41560
108000) 440560 (4.08
432
850

$$z : x^2 :: a : (z-x)^2$$

$$ax^2 = z^2 - 2zx + zx^2$$

$$(a-z)x^2 + 2zx = z^2$$

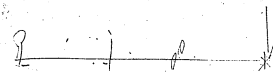
$$4(a-z)^2x^2 + (-) + 4z^2z^2 = 4z^2(a-z) + 4z^2z^2$$

$$= 4z^2(a)$$

$$2(a-z)x + 2z = 2\sqrt{az}$$

$$x = \frac{\pm\sqrt{az} - z}{a-z}$$

$$x = \frac{z(\sqrt{az} - z)}{a-z}$$



$x : a^2 :: x - 2 : 50^2$

$2^2 x = a^2 x - a^2 2$

$x(2^2 - a^2) = a^2 d$

$x = \frac{a^2 d}{a^2 - 2^2}$

a = 17,	x = 59.6
a = 18,	x = 60
a = 19,	x = 60.4
a = 20,	x = 60.8
a = 21,	x = 61.1
a = 22,	x = 61.5
a = 23,	x = 61.8
a = 24,	x = 62.1
a = 25,	x = 62.4
a = 26,	x = 62.6
a = 27,	x = 62.9
a = 28,	x = 63.1
a = 29,	x = 63.4
a = 30,	x = 63.6
a = 31,	x = 63.8
a = 32,	x = 64.
a = 33,	x = 64.2
a = 34,	x = 64.4
a = 35,	x = 64.6
a = 50,	x = 66.7

$$x = \frac{80\sqrt{a}}{\sqrt{2}+\sqrt{a}}$$

$$x\sqrt{a} + x\sqrt{b} = 2\sqrt{a}$$

$$\sqrt{a}(x-2) = -x\sqrt{b}$$

$$a(x-2)^2 = bx^2$$

$$a = \frac{bx^2}{(x-2)^2}$$

$$\sqrt{a}(2-x) = x\sqrt{b}$$

$$a(2-x)^2 = bx^2$$

$$a = \frac{bx^2}{(2-x)^2}$$

$$\frac{80\sqrt{2}}{\sqrt{2}+\sqrt{2}}$$

$$\frac{80\sqrt{2}}{\sqrt{4}+\sqrt{2}}$$

$$\frac{80}{3} = 26.7$$

$$\frac{6400b}{}$$

$$x = \frac{2\sqrt{a}(\sqrt{a} \pm \sqrt{b})}{a-b}$$

$$= \frac{2\sqrt{a}}{\sqrt{a} \pm \sqrt{b}}$$

$$x\sqrt{a} \pm x\sqrt{b} = 2\sqrt{a}$$

$$\sqrt{a}(2-x) = \pm x\sqrt{b}$$

26.7

$a = 1,\ x = 33.1$

$a = 2,\ x = 40$

$a = 3,\ x = 44$

$a = 4,\ x = 46.9$

$a = 5,\ x = 49$

$a = 6,\ x = 50.7$

$a = 7,\ x = 52.1$

$a = 8,\ x = 53.3$

$a = 9,\ x = 54.4$

$a = 10,\ x = 55.3$

$a = 11,\ x = 56.1$

$a = 12,\ x = 56.8$

$a = 13,\ x = 57.5$

$a = 14,\ x = 58.1$

$a = 15,\ x = 58.6$

$a = 16,\ x = 59.1$

$$\sqrt{a} = \frac{\pm x\sqrt{b}}{2-x}$$

$$a = \frac{bx^2}{(\frac{2-x}{x})^2}$$

2.2361
1.4142

2.4493
1.4142

2.6457
1.4142

2.8284
1.4142

3.1623
1.4142
4.4720

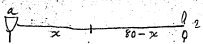
3.3166
1.4142
4.7208

3.4641
1.4142
4.8783

3.6055
1.4142

3.7417
1.4142

3.8730
1.4142
5.2872



$$a : x^2 :: 2 : (80-x)^2$$

$$a(80-x)^2 = 2x^2$$

$$6400a - 160ax + ax^2 = 2x^2$$

$$(2-a)x^2 + 160ax = 6400a$$

$$4(2-a)^2x^2 + (-) + (160a)^2 = 4(2-a)(6400a) + (160a)^2$$

$$= 51200a$$

$$2(2-a)x + 160a = 160\sqrt{2a}$$

$$x = \frac{160(\sqrt{2a}-a)}{2(2-a)} = \frac{80(\sqrt{2a}-a)}{2-a}$$

$$= \frac{80\sqrt{a}(\sqrt{2}-\sqrt{a})}{2-a} = \frac{80\sqrt{a}}{\sqrt{2}+\sqrt{a}}$$

$$= \frac{80\sqrt{a}}{1.4142+\sqrt{a}}$$

$$-4x^2 + 4a^2 = 4a^2b$$

$$a : x^2 :: b : (l-x)^2$$

$$bx^2 = al^2 - 2alx + ax^2$$

$$(a-b)x^2 - 2alx = -al^2$$

$$4(a-b)^2x^2 - (-) + 4a^2l^2x^2 = -4al^2(a-b) + 4a^2l^2$$

$$= +4a^2l^2b$$

$$2x(a-b) - xal = \pm xl\sqrt{ab}$$

$$x = \frac{\pm l\sqrt{ab}}{a-b} + \frac{al}{a-b}$$

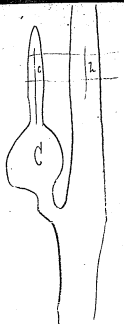
$$x = \frac{al \pm l\sqrt{ab}}{a-b}$$

$$x = \frac{l\sqrt{a}(\sqrt{a}+\sqrt{b})}{a-b}$$

$$\frac{l\sqrt{b}(\sqrt{b}-\sqrt{a})}{-(b-a)} = \frac{l\sqrt{b}}{\sqrt{b}+\sqrt{a}}$$

$$x = \frac{l\sqrt{a}}{\sqrt{a}+\sqrt{b}}$$

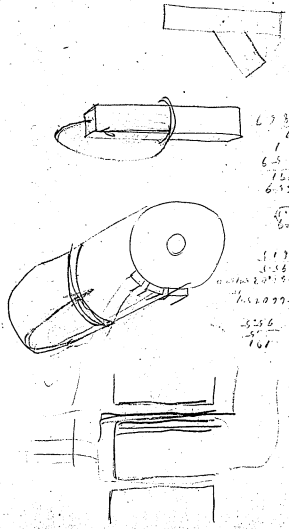
$x^2+y^2=R^2$	$\frac{\pi R^2}{4}$	$\frac{4\ 3.141589}{.7854}$	
.6056			
.6082	0786	3028	2846.58
6108	0789	3041	2870.81
6134	0793	3054	2895.18
6160	0796	3067	2919.66
6185	0799	3080	2944.26
6211	0803	3093	2968.94
6237	0806	3106	2993.73
6263	0809	3119	3018.63
6288	0813	3132	3043.62
6314	0816	3144	3068.78
6340	0819	3157	3093.93
6366	0823	3170	3119.24
6391	0826	3183	3144.65
6417	0829	3196	3170.17
	0833	3209	3195.78



$r : 1\text{ at} :: h : 760$

$r = \frac{h}{760}$

$R : \frac{h}{760} :: c : C$

$R = \frac{hc}{760C}$

3/4" vacuum. temp.